

**Science and Mathematics Education Centre**

**The Role of Christian Religious Beliefs about Students' Attitudes  
and Reasoning towards Biotechnology Issues in Victorian Christian  
Schools**

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**This thesis is presented for the Degree of  
Doctor of Philosophy  
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## DECLARATION

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

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## **ABSTRACT**

The inclusion of socioscientific issues in the Science classroom provides an ideal framework from which teachers can explore the cultural and ethical perspectives of science that are a core feature of the Australian Curriculum and other international science programs. The technological advances of modern biotechnology provide teachers with a number of opportunities to explore socioscientific issues, which the literature suggests has the ability to engage students in the learning process, enhance students' reasoning and aid in moral development. Although some attempt has been made to understand cultural differences in students' attitudes towards issues in biotechnology and their informal reasoning across international and regional boundaries, there is limited research about the differences that exist between students who identify with one of the Christian worldviews and those students who do not.

Although the beliefs and cultural norms of Christian worldviews have been shown to impact an individual's attitude towards a number of biotechnologies (Evensen et al., 2000), little research has explored the role that a Christian perspective has on secondary students' reasoning, and ultimately upon their acceptance of modern biotechnology issues.

The field of biotechnology, and especially modern biotechnology, incorporates a range of socioscientific issues, including the production of genetically modified organisms, therapeutic and reproductive cloning, pre-implantation genetic screening, and in vitro fertilization (IVF). These technologies are associated with diverse ethical perspectives and religious ideologies; they therefore provide a useful framework from which to assess the influence of an individual's Christian worldview on their attitudes towards, and reasoning about, a range of controversial, but societally relevant, scientific issues.

This study used a mixed-methods approach to investigate the role that students' Christian religious beliefs played in their attitudes and informal reasoning about biotechnology issues. Data were collected from 177 senior secondary students (16-18 year olds) across three independent Christian secondary schools in Victoria, Australia. A questionnaire and semi-structured student interviews were used to gather quantitative and qualitative data about students' religious beliefs, with specific

reference to Christian beliefs and practices, as well as to their attitude about a range of biotechnological issues.

Statistical methods were used to analyse the associations between religious worldview and attitudes towards biotechnology, while the identification of categories of ethical arguments, and the classification of modes of informal reasoning, provided an insight into the students' thinking about these issues.

This thesis adds to the current literature by providing evidence that both male and female secondary students who were identified as having a Christian worldview had a more negative attitude towards biotechnology and were more concerned about the use of technologies involving cloning, genetic screening, IVF, and the modification of plants, animals and humans, than students who did not have a Christian worldview. Students with a higher degree of religious belief demonstrated less use of rational reasoning and a greater reliance on intuitive reasoning in their responses to socioscientific issues when compared with their less religious peers. This research identified that few students could provide arguments for their decisions about specific biotechnologies that were grounded in their religious worldview. However, the students' arguments identified in this study, which included the ethical arguments, 'God's will', and 'God is Creator', provided some insight into the differing attitudes about biotechnology that were shown to exist between the Christian and non-Christian cultural groups.

This research provides science educators an insight into the culture and values of students with a Christian worldview by describing *what* students think about issues in biotechnology as well as *how* they think about these issues. The findings highlight the need for initiatives that will encourage the increased use of rational and emotive reasoning by students, and that will allow them to acknowledge the presuppositions of their belief system and how these influence their attitude towards controversial issues in science. By providing additional insight into students' attitudes towards biotechnology, this research can be used by educators to engage students who come from a Christian cultural background with socioscientific issues in a manner that challenges and extends students' thinking, while remaining sensitive to their Christian worldviews.

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If we decide that we do not have the time to stop and think about right and wrong, then we do not have time to figure right from wrong, which means we do not have time to live according to our model of right and wrong, which means, simply put, we don't have time for lives of integrity.

-Stephen L. Carter, *Integrity*

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## **Chapter 1**

### **INTRODUCTION TO THE RESEARCH STUDY**

#### **1.1 INTRODUCTION**

The purpose of this research is to investigate the role of Christian religious beliefs on students' attitudes and reasoning towards biotechnology issues within the context of Australian Christian schools. This will be achieved using the framework provided by the socioscientific research community, which values the role of cultural perspectives in the process of student reasoning about controversial issues in science. The purpose of this first chapter is to provide an introduction to the topic under investigation and to outline the necessary background information relevant to this current study. After providing a background to the key concepts involved in the study, Chapter 1 continues with an outline of the conceptual framework before detailing the research questions that will guide this study. The context of the study is provided, along with a short comment on the personal views and perspectives of the researcher. This chapter concludes with a summary of Chapter 1 and an overview of this thesis.

#### **1.2 BACKGROUND TO THE STUDY**

With the inclusion of biotechnology topics into many school science curricula and the prevalence of biotechnology issues in the media, questions about student attitudes and their engagement with biotechnology issues have become increasingly more relevant. Now, more than ever, it is important for students to understand not only the science of biotechnology but also the moral issues that are associated with its development and use. It is, after all, today's students who will be developing, using and making policy decisions about the biotechnology of the future. A number of studies (Chen & Raffan, 1999; Dawson & Schibeci, 2003; Gunter, Kinderlerer, & Beyleveld, 1998; Lock & Miles, 1993) suggest that students are not fully equipped to be making these decisions. At a more fundamental level, much more work needs to be done in understanding the attitudes and reasoning processes of students. Unless moral education regarding biotechnology is grounded in an understanding of students' moral positions, the full potential of enriching student understanding will not be realised.

This is no small task as the field of biotechnology is a large discipline and the ethical

dilemmas that it raises are numerous and multifaceted. Biotechnology is identified by CSIRO (n.d.) on its technology education website TechNyou as the use of living organisms, or their products, to modify human health and the human environment . Cook and Fairweather (2005) have noted that in recent years the term has often been used in a more restricted sense to refer to the process of genetically modifying organisms (GMO). This study uses the term, ‘biotechnology’, in its broad definition, which includes not only GMOs, but also the whole range of technologies, from the production of cheese to the cloning of individuals.

### **1.2.1 Socioscientific Issues**

In recent years there has been an inclusion in the Australian secondary school science curricula of issues that arise from science that are considered controversial in nature. Examples of their inclusion can be found in the Victorian Certificate of Education Biology study design (Learner, 2012), which includes the statement.

The ability to apply technologies that can change the genetic composition of individual organisms and species, including humans, raises controversial issues for individuals and society. Students examine these issues and consider their implications from a variety of perspectives. (p. 26)

In the junior science curriculum, which can be found at the Australian National Curriculum website, [australiacurriculum.edu.au](http://australiacurriculum.edu.au), the Year 10 Science as a Human Endeavour strand of the Australian National Curriculum (ACARA, n.d. Content Descriptions - ACSHE195) calls for students to examine how,

Advances in science and emerging sciences and technologies can significantly affect people’s lives. ... [while] investigating the applications of gene technologies such as gene therapy and genetic engineering.

Students should also be able to show that:

The values and needs of contemporary society can influence the focus of scientific research ... [by] considering the use of genetic testing for decisions such as genetic counselling, embryo selection, identification of genetic mutations and the use of this information for personal use or by organisations such as insurance companies or medical facilities (ACARA, n.d. Content Descriptions - ACSHE230).

The Australian Science Curriculum identifies the need for students to understand the combined role of science, ethical, economic and social arguments in the decisions regarding personal and community issues (ACARA, n.d. Content Descriptions - ACSIS206). This appreciation that science needs to be studied within a social

context was becoming evident in 1971 when Gallagher (1971) commented that.

For future citizens in a democratic society, understanding the interrelationships of science, technology and society may be as important as understanding the concepts and processes of science. (p 337)

This recognition that science needs to be placed within a broader social context gave birth to the Science, Technology and Society movement as a pedagogical strategy addressing the science and society interface. More recently, a fresh framework for exploring the interplay between science and societal issues, the socioscientific (SSI) movement, has been developed centring on students' personal, cognitive and moral development. The aim of SSI education is "to stimulate and promote individual intellectual development in morality and ethics as well as an awareness of the interdependence between science and society" (Zeidler, Sadler, Simmons, & Howes, 2005, p. 360). Socioscientific issues are broadly defined in the literature as socially relevant issues, often associated with controversy and social debate, which result from the products or the processes of science. (Fleming, 1986; Kolstø, 2001; Sadler & Zeidler, 2004, 2005a). The SSI framework, which recognises the importance of cultural issues and students' belief systems (Zeidler et al., 2005), provides an ideal framework from which to explore the role of religious belief in students' attitudes towards biotechnology issues.

### **1.2.2 Biotechnology Advances and Social Challenges**

The past fifteen years have seen incredible advances in biotechnology. As an undergraduate student in 1997, I was amazed along with the rest of the world as I read about Dolly the sheep, the first example of somatic cell cloning. Since then, we have seen many more achievements, including pet fish that glow in the dark (Bhattacharya, 2003), a cloned cow from the cells of a carcass (Ghosh, 2010) and the creation of the first synthetic cell by the J. Craig Venter Institute (Gibson et al., 2010).

The developments in this field of science have not gone unchallenged, with a number of vocal groups protesting the use of a range of biotechnology applications. Greenpeace Australia, speaking through their website, <http://www.greenpeace.org/australia>, are highly critical of all genetically modified (GM) crops. In 2011, protesters destroyed a trial plot of GM wheat near Canberra, Australia (Holland, 2011), underscoring the deep controversy that exists in Australia

regarding biotechnology issues. Indeed, two Australian states, South Australia and Tasmania, currently have a moratorium on all GM crops, while Western Australia, Victoria and New South Wales all have significant restrictions on the commercial use of GM crops, mostly limited to GM canola. (Refer to the Department of Agriculture and Food, government of Western Australia website [www.agric.wa.gov.au](http://www.agric.wa.gov.au)). The controversy that surrounds this limited representation of socioscientific issues exemplifies the growing need for students to be able to negotiate these issues and ultimately contribute to the decisions that society makes regarding the use of these technologies.

### **1.2.3 Attitudes towards Biotechnology**

Attitudes are perceived as being an internal thought process, which is expressed in an individual's thought, feelings and behaviour (Eagly & Chaiken, 1998). Within the general Australian population, studies have shown that attitudes towards biotechnology are highly variable (Cormick, 2002). While a number of studies have explored Australian students' attitudes towards biotechnology (Cavanagh, Hood, & Wilkinson, 2005; Dawson, 2007), there has been very little research that explores the underlying influences behind students' attitudes. This study explores the ideas of Scholderer and Frewer (2003), who suggest that attitudes are determined by more general views held by the student. This view is supported by Cook and Fairweather (2005), who noted a strong link between an individual's worldview and attitudes towards biotechnology.

If rational debate is to proceed, there needs to be understanding on both sides about the ethical dimensions to this debate. As today's students will contribute to tomorrow's public opinion, and some specifically to the voice of the scientific community, a desirable aim for teachers of secondary school students is to provide them with an ethical construct from which to evaluate biotechnology uses, thereby allowing them to develop rational and informed arguments for their position. Two broad principles guide the need to better understand students' attitudes towards biotechnology. Firstly, society needs to decide on the future direction of research in this area; more specifically, individuals need to decide what they will accept in terms of biotechnology. However, the underlying belief systems influencing student attitudes are poorly understood. This research examines the factors influencing attitudes towards biotechnology and how those influences are incorporated into

students' attitudes. This information will allow educators to better develop educational tools for students to aid their knowledge and understanding not only of issues in biotechnology, but the personal worldviews of individual students. Secondly, it is important for proponents of biotechnology to better understand the role that belief systems play in determining attitudes to biotechnology if they are to adequately address the concerns of their critics. Hoban, Woodrum, and Czaja (1992) and Frewer, Howard, and Shepherd (1997) indicate that moral objection to the use of biotechnology has a significant effect on public opposition to the use of biotechnologies.

The differing attitudes towards, and values placed on, biotechnology generates considerable discussion, and sometimes angst, between proponents and objectors. For this reason, a simple description of the views held by individuals will provide only limited guidance in the understanding and development of biotechnology education. As Cormick and Ding (2005) noted:

While many surveys have been undertaken to find out what the public thinks about gene technology, or to map public concerns, there has been less work concentrating on the underlying causes of community concern, which need to be fully understood in order to minimise public rejection of new technologies with broad benefits. Also, many policy decisions by industry, researchers and government, referring to public attitudes towards gene technology use over-simplified or erroneous statements of public attitudes. A better understanding of community concerns and factors of acceptance enables for more effective education, consultation and community uptake of new technologies. (p. 2)

More pertinent then, is an understanding of the factors, or social domains, that underpin those attitudes. Aikenhead (1985) identifies that in collective decision-making there are a number of overlapping social domains that impinge upon each other, including religion, ethics and socio-political ideologies. He goes on to argue that it is important to identify the domains that are relevant to the decision being made, in order to avoid mediocre decisions.

#### **1.2.4 Moral Reasoning**

The importance of moral reasoning within an educational setting has recently been highlighted with the integration of ethical thinking into the Australian Curriculum (ACARA, n.d.). In this document, which now marks the standard for all pre-tertiary education in this country, a justification is made for the inclusion of ethics education in Australian schools.

In the Australian Curriculum, students develop ethical understanding as they identify and investigate the nature of ethical concepts, values and character traits, and understand how reasoning can assist ethical judgment. Ethical understanding involves students in building a strong personal and socially oriented ethical outlook that helps them to manage context, conflict and uncertainty, and to develop an awareness of the influence that their values and behaviour have on others. (Ethical understanding, para. 1)

The products of moral reasoning, which largely determine an individual's attitude towards biotechnology, are often differentiated as being either intrinsic or extrinsic concerns. Christian belief may play a role in both but has a potentially significant influence when discussing intrinsic concerns. Extrinsic concerns, such as those about the risks and safety of biotechnology, are essentially a matter of science and trust in science, although the motivation for questioning the technology may come from religious, altruistic, financial or other concerns. Utilitarian philosophies are concerned mostly with extrinsic concerns because it is the consequences of the technology that makes it morally right or wrong (Reiss & Straughan, 1996). Intrinsic concerns are about the unnaturalness of biotechnology. These issues are more difficult to address, as they cannot be decided on based on scientific processes. It would be expected that being grounded in a deontological philosophy, Christian belief would tend to focus on intrinsic concerns and as such deal with duty based morality that makes certain acts, based upon universal principles, necessary regardless of the consequences (Reiss & Straughan, 1996). The very nature of intrinsic concerns means they will generally trump extrinsic concerns in any consideration between the two. If a particular biotechnology is intrinsically wrong, then any extrinsic considerations are meaningless as nothing can reverse the intrinsic wrongness.

The reasoning students use to decide about ethical issues is important as it provides an insight into how an individual moves from his or her worldview to a moral decision. Identifying the patterns and trends in students' informal reasoning, and encouraging students to recognise the type of reasoning they are using, is possibly the first step in the process of developing a curriculum that provides students with the skills to make informed and consistent decisions about biotechnological issues. By assessing students' inclusion of religious beliefs in their informal reasoning, a more complete picture of students' attitudes towards biotechnology can be achieved.



### 1.2.5 Christian Worldviews and Attitudes Towards Biotechnology

Data from the Australian Bureau of Statistics (2011) show that 61% of Australians identify themselves as Christian. While an affiliation to Christianity does not infer a level of spirituality or religiosity, it does indicate that the assumptions inherent in Christian worldviews are widespread within the Australian population. A New Zealand study (Coyle, Maslin, Fairweather, & Hunt, 2003) concluded that:

[Spiritual values] are embedded in everyday life and practise. Moreover, spiritual views provide people with moral anchors from which to determine appropriate ethical behaviours; ethics that filter into debates on regulatory controls over biotechnology research. (p84)

This view is supported by the work of Regnerus and Smith (1998), who demonstrated that Evangelical Christians in America are the group most likely to view their religion as being important in deciding opinions about public affairs. Research that specifically examines Australian students' attitudes and compares them with religious beliefs could not be located; however, outside of Australia some evidence does exist in the literature supporting the position that people who adhere to a Christian belief tend to be less accepting of biotechnology (John Evans, 2002; Jordahl, 1993). There is, however, some ambiguity in the literature, with Scheitle (2005) reporting that church attendance and personal religiosity increased optimism towards biotechnology.

### 1.2.6 Informal Reasoning

Socioscientific issues are controversial in their nature and often difficult for students to resolve because they have no definitive solution. The thinking that a student does in an attempt to resolve such issues is termed *informal reasoning* and incorporates both the cognitive and affective processes used by the students (Means & Voss, 1996; Sadler & Zeidler, 2005a; Zeidler et al., 2005). Sadler & Zeidler (2005a) identified three *patterns of informal reasoning* that individuals utilise in their attempt to resolve these issues:

1. Rationalistic reasoning: utilising reason based considerations.
2. Emotive reasoning: utilising empathy- and sympathy-based considerations.
3. Intuitive reasoning: unexplainable immediate reactions.

Informal reasoning can be used to explore the types of thinking that students use when faced with socioscientific issues and thereby give insight into the development of student's attitudes towards biotechnology.

### 1.3 RESEARCH OBJECTIVES

While many valuable studies have been completed on student attitudes towards biotechnology, very little has focused on Australian students. This research adds to the body of literature that explores an Australian perspective of student attitudes towards biotechnology by attempting to identify how beliefs about biotechnology and religious beliefs interact to influence student's attitudes and reasoning on biotechnology issues. New information will be presented that can be used by educators in designing and implementing biotechnology education programs that directly address the issues and concerns of a student's Christian worldview and hopefully contribute to students developing a logical and internally consistent approach when assessing biotechnologies.

A trend of negative attitudes towards biotechnology within more conservative Christian groups has been noted in the United States. However none of the research examined secondary school students and was limited in the focus of biotechnology issues, assessing attitudes towards only a narrow field such as cloning (John Evans, 2002), and biotechnology involving humans (Jordahl, 1993), but never encompassing a broad definition of biotechnology as used in this research. By using a larger range of biotechnology issues, it is anticipated that a more holistic understanding of the interaction between religious faith and attitudes towards biotechnology can be obtained.

### 1.4 CONCEPTUAL FRAMEWORK

This study brings together three broad areas of research to explore and better understand the socioscientific field of biotechnology and utilises research about biotechnology attitudes, religious beliefs (Christian worldview) and informal reasoning as a framework from which to approach this multifaceted area of study. The inter-relationship between these areas of study are summarised in Figure 1.1. The basis of this framework is that religious belief may have an influence over an individual student's attitudes towards biotechnology and their informal reasoning. By examining these two areas through the lenses of an individual's belief system, a clearer picture of student's interaction with biotechnology issues becomes evident.

The methodological interaction between these fields, as utilised in this study, has also been shown in Figure 1.1, with religious belief and biotechnology being explored through quantitative approaches, while qualitative approaches have been used to explore the relationship between informal reasoning and religious belief as well as between informal reasoning and biotechnology attitudes. A justification for the methodologies used is described in Chapter 3.

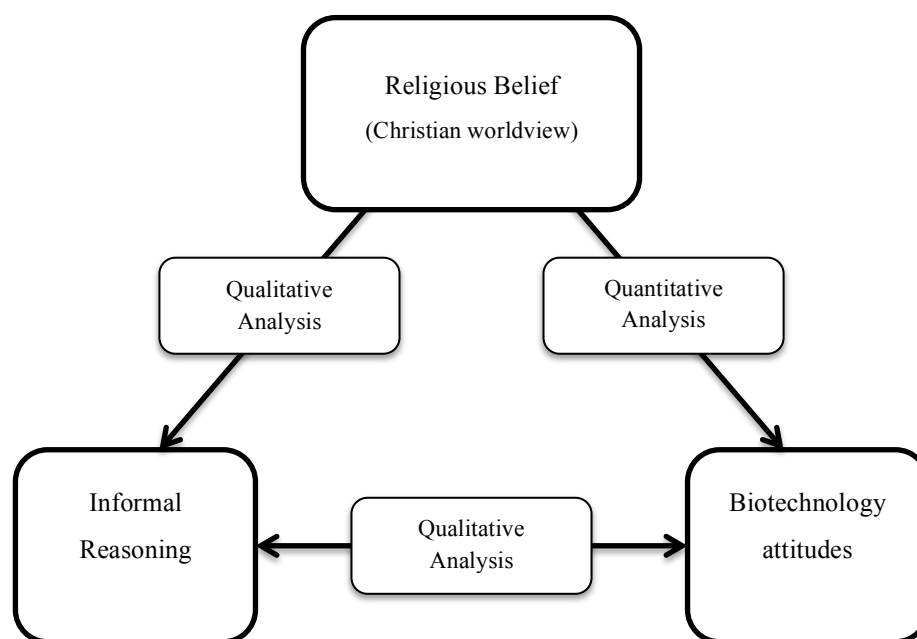


Figure 1.1 *Methodological interaction of the key research areas examined in this study.*

## 1.5 RESEARCH QUESTIONS

Some research has suggested that there is a negative correlation between religious belief and an individual's acceptance of biotechnology. The extent to which this is the case, particularly amongst Australian secondary students, remains unclear and this has led to the formation of the first research question.

1. How does religious belief act as a predictor of attitudes towards biotechnology?

The identification of patterns of informal reasoning has been a useful tool in analysing student perceptions of socioscientific issues, particularly those involving biotechnology (Dawson & Venville, 2009; Means & Voss, 1996; Sadler & Zeidler, 2005b; Topçu et al., 2011; Wu & Tsai, 2007; Wu & Tsai, 2010). No studies have

attempted to measure if the patterns of informal reasoning differ for students who are approaching the issue from the perspective of a Christian belief structure. The second research question explores this relationship between belief and informal reasoning by asking:

2. Does the acceptance of a Christian belief affect students' patterns of informal reasoning?

It is expected that some individuals with a Christian faith tradition will use their beliefs as part of an argument for or against certain aspects of biotechnology. It would, however, be useful to know the frequency at which religious beliefs are incorporated into the student's reasoning. Furthermore the types of ethical arguments by which their beliefs are expressed would provide valuable information as to the role of the individual's belief system in determining their acceptance of biotechnology. The final question therefore asks:

3. How are student's religious beliefs incorporated into their informal reasoning about biotechnology?

Through an examination of the three research questions outlined above a clearer and more nuanced picture of the relationship between Christian religious beliefs and students' attitudes towards biotechnology has been achieved.

## 1.6 CONTEXT OF THE STUDY

This study was undertaken in three faith-based secondary schools located across metropolitan Melbourne, Australia. In Australia, faith-based schools are financially supported by a religious organisation or denomination, as well as receiving additional financial support through the collection of tuition fees and some state and federal funding. The three schools that participated in this study were from Adventist Schools Victoria (ASV), part of the global education system run by the Seventh-day Adventist Church. The three schools were low fee paying schools and not selective, therefore a diverse range of religious faiths, nationalities and socioeconomic groups were represented. The schools have an ICSEA (Index of Community Socio-Educational Advantage) value of between 1040 and 1055, a score that is marginally above the national average for that scale. The Index of Community Socio-Educational Advantage (ICSEA) gives an approximation of the socio-academic advantage of students attending a school. This measure, calculated by the Australian Curriculum, Assessment and Reporting Authority (ACARA), provides a numerical

scale representing the magnitude of the educational advantage resulting from key factors that are known to influence a student's educational outcome, such as the level of parents' education and income, geographical location of the school and indigenous population at the school, amongst other factors (ACARA, 2013). The median ICSEA level is calculated by ACARA (2013) to be 1000 with a standard deviation of 100, and typically ranges from 500 (very low socio-educational advantage) to 1300 (very high socio-educational advantage).

The data was collected throughout the 2010 school year with the researcher personally visiting each school and class to administer the survey component of the study. The sample for this study involved students from Years 11 and 12 (aged 16, 17 and 18 years of age) as it was thought that they had the maturity to engage in this sometimes controversial topic and they were also at an age where they were starting to develop their own opinions about these topics. All senior students in the three participating schools were invited to take part, with a total of 181 choosing to do so, providing a final participation rate of 85%. The participating students were working towards the completion of their Victorian Certificate of Education (VCE), which is the certificate the majority of students in the state of Victoria receive after completing their secondary education. To achieve this certificate students are required to complete a number of VCE approved subjects, generally over the two years that they are in Year 11 and Year 12 (VCAA, n.d.).

A mixed methods design was utilised. The quantitative component of the study involved the use of a questionnaire designed to measure attitudes towards biotechnology and students' religious worldview. Statistical analysis was used to determine the relationships in the data. The qualitative component of the study explored the informal reasoning of students with two data collection tools. The first, a questionnaire with written responses, was supported with four focus group interviews consisting of four to five students in each group. Analysis of the qualitative data involved classifying student statements according to the informal reasoning pattern and the use of religious claims and arguments.

## 1.7 PERSONAL VIEWS AND PERSPECTIVES

I approach this research through the perspective of my own personal worldview, influenced as such by my personal experiences and belief system. My current

employment is at a faith-based co-educational school where I have eleven years of experience teaching senior biology and physics. My faith and my science training are embedded into my worldview and therefore influence my personal attitudes towards biotechnology, which is one of cautious optimism. From a science perspective, I embrace the advantages that modern biology has brought to society and may yet provide. I have significant trust in the processes of science and the scientific community to ensure that the applications of biotechnology provide minimal risk to individuals, communities and the environment. My scientific perspective is augmented by my Christian faith, which provides the moral lens to my worldview. Two key principles guide my approach to controversial issues such as biotechnology. Firstly, I believe that I have a duty to care for the rest of humanity, especially those individuals and groups who are marginalised in society, including the poor, the hungry and the sick or injured. Secondly, I believe that I have a duty to care for the environment, including the protection of plant and animal life. Such ideals are certainly not unique to any particular faith position; however, for me it is a personal faith that drives these convictions. I feel that science will have an increasingly important role to play in caring for humanity and the environment. Indeed, I would argue that in many cases, society has a moral responsibility to utilise biotechnology when it can alleviate suffering of humans and minimise harm to the environment. And yet I share the concerns expressed by many commentators over its use in such a way that may harm the environment or further disadvantage those individuals who are marginalised. Distinguishing between the appropriate and inappropriate use of biotechnology is not always easy, and to this extent I believe that students should be provided not only with the knowledge to understand science, but also the moral reasoning skills with which to assess the uses that science is put to. In this way they can help to guide society in deciding what is an appropriate use of biotechnology.

## 1.8 SUMMARY OF THESIS

The first chapter in this thesis introduces the research project by providing a background to the research and outlining its objectives. A conceptual framework is included that shows where this project fits in with the literature. The research questions addressed in the project are articulated and the context of the study described, along with a brief overview of the methodology used to address the three research questions.

Chapter 2 presents an extensive review of the literature as it pertains to this study, including a review of the literature involving socioscientific issues, informal reasoning, biotechnology attitudes and the development and measurement of a Christian worldview. Studies that provide specific insight into the role of religious belief in biotechnology attitudes are evaluated.

Chapter 3 reports on the methodology used in this study and includes a description of the techniques used to collect and analyse the data used in this investigation.

The results obtained from the analysis of data are reported across three chapters, with Chapter 4 reporting on the results obtained from the quantitative analysis of the data relevant to Research Question 1 and Chapter 5 reporting on the results obtained from the quantitative analysis of the data relevant to Research Question 2. Research Question 3 is reported on in Chapter 6, which includes the results obtained from the qualitative and the quantitative analyses of the data. For each chapter the key findings are highlighted.

Chapter 7 provides an in-depth discussion of the results from both the qualitative and quantitative data analyses relevant to each of the three research questions. The research findings are placed within the context of the relevant literature, and the chapter concludes with a general discussion and summary of the key findings.

Chapter 8 concludes the report on this investigation with a summary of the study and its findings. A summary of the thesis and the research findings is provided and this is followed by a description of the distinct contributions made by the study, some comments on the limitations of the study, and a discussion of the practical implications of the findings before providing recommendations for future research.

This chapter is followed by Chapter 2, which provides a review of the literature associated with students' attitudes towards biotechnology, informal reasoning and Christian worldviews, through the contextual framework of the socioscientific movement.

## **Chapter 2**

### **LITERATURE REVIEW**

#### **2.1 INTRODUCTION**

Chapter 1 provided an overview of the purpose of this study, which was to examine the role of Christian worldviews in secondary students' attitudes and informal reasoning regarding biotechnology issues. This second chapter will provide an overview of the literature that pertains to the achievement of that purpose. To achieve this purpose, three research questions were developed. The first question sought to determine if religious belief acted as a predictor of attitudes towards biotechnology. The second question asked if the acceptance of a Christian belief affected students' patterns of informal reasoning. The purpose of the final question was to determine how students' religious beliefs are incorporated into their informal reasoning about biotechnology.

Whilst using the socioscientific framework to address these questions, it was necessary to bring together the three fields of study consisting of informal reasoning, biotechnology attitudes, and measures of religious worldview.

This chapter reviews the relevant literature that pertains to the three fields of inquiry that intersect this present study: students' attitudes towards biotechnology, religious worldviews, and informal reasoning. A diagram outlining the intersection of these three fields of study and how it applies to this current research, including a selection of the significant studies that are relevant to each field, has been presented in Figure 2.1.

After the introductory section, the second section of this chapter examines the literature on socioscientific issues and the socioscientific issues movement, and places this study in the context of that field. A review of the literature that addresses informal reasoning in socioscientific issues is then presented in the third section, with the fourth section investigating attitudes towards biotechnology and providing a description of the formation of attitudes as well as the methods used to measure them. In the fifth section moral judgement and Christian worldviews are discussed, including a definition of both, along with how the concept of a Christian worldview can be measured. The sixth section examines the intersection of Christian worldviews with biotechnology attitudes, through a description of the religious



concerns and support for biotechnology as well as a review of the current research on religious belief and attitudes towards biotechnology. The concluding section provides a summary of the literature addressed in Chapter 2.

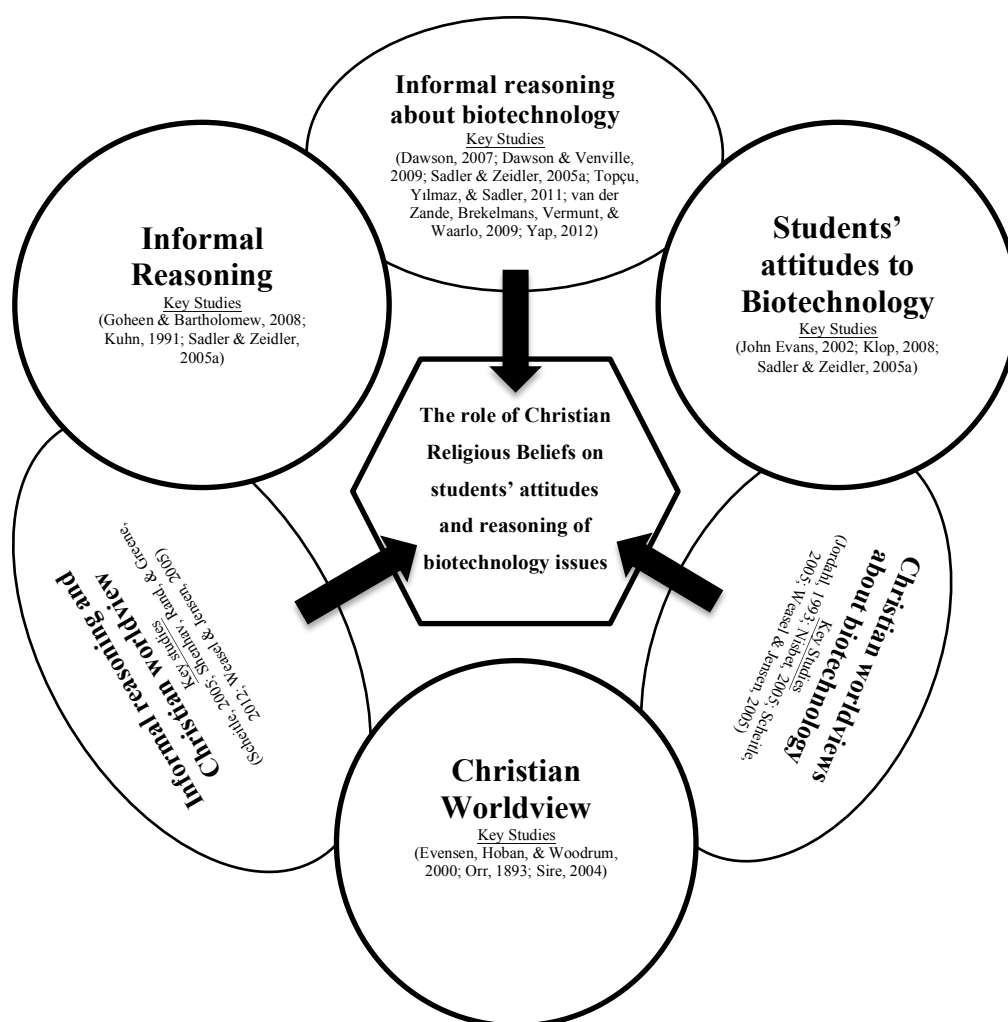


Figure 2.1 *Major areas of inquiry addressed in the literature review.*

## 2.2 SOCIOSCIENTIFIC ISSUES

This section describes the historical development of the socioscientific issues (SSI) movement and highlights some of the educational benefits of using this approach to science teaching. Justification is provided for the placement of this study within the SSI movement through an exploration of two pedagogical issues that have been identified with the socioscientific framework: classroom discourse and cultural issues.

### **2.2.1 Historical Development and Scope of SSI**

Science educators have long realised the need for students to understand the interrelationship that exists between science and society with research and dialogue in this area taking place for as long as the field of science education has been in existence (DeBoer, 1991). Gallagher (1971) was one of the first to highlight the importance of placing scientific knowledge within a social construct and since then ongoing research has continued to highlight the importance of this interaction between science and society in developing students' scientific literacy. Leading up to the 1980s, an effort was made to make science more relevant and appropriate to students; to achieve this end, a number of science courses and programs began including material that placed science in a social context in an effort to make science more socially and culturally relevant to students. In a review of the curriculum material then available, Ziman (1980) coined the term Science-Technology-Society (STS). The STS movement grew quickly during the 1980s, both in its popularity with science teachers and as a theoretical framework for teaching science, such that it was described by Hart and Robottom (1990) as a paradigm shift for the field of science education. STS is essentially a method of teaching science that places the context of the issues as a central theme that can then be used as a mechanism for teaching not only science concepts but also the process of scientific inquiry (Yager, 1993). It was adopted by the National Science Teachers Association (1982) as a central goal for science education, stating that:

The goal of science education during the 1980s is to develop scientifically literate individuals who understand how science, technology and society influence one another and who are able to use their knowledge in their everyday decision making. (p. 1)

Throughout the 1990s, the enthusiasm for STS started to wane with science educators such as Shamos (1995) noting that the movement did not fulfil its purpose of being exciting and relevant to students. Moreover, Zeidler et al. (2005) identified that the STS movement had failed to give students a voice about the issues being examined, nor did it allow for students to approach those issues from a personal perspective, grounded in the cultural background of the students. Zeidler et al. (2005) further suggested that STS, which lacked a grounded theoretical framework, did not provide for the moral or character development of the students. In what has largely been seen as a successful reinterpretation of the STS model, an additional dimension

to the STS framework was added that includes the beliefs and life experiences of students (Zeidler et al., 2005). This reworking of the STS framework was titled socioscientific issues (SSI) and its main aim as a movement is to focus “specifically on empowering students to consider how science-based issues and the decisions made concerning them reflect, in part, the moral principles and qualities of virtue that encompass their own lives, as well as the physical and social world around them” (Zeidler et al., 2005, p. 360).

Socioscientific issues are generally described in the literature as being issues that involve science but that also have a strong cultural or ethical dimension to them such that it is often difficult for individuals and groups to come to a consensus about the use of the technology and science at the centre of the issue. These socioscientific issues are often at the centre of media discussions and are often influenced by personal, political, religious and other societal views (Kolstø, 2001; Sadler, 2004; Zeidler & Keefer, 2003; Zeidler et al., 2005). In a discussion about balancing the sometimes conflicting concerns and desires of the individual stakeholders associated with socioscientific issues, Kolstø (2006) outlines the underlying tensions that dominate much of the debate about these issues:

Because we have different wishes, values, and beliefs, society is loaded with these sorts of conflicts. Such conflicts cannot be solved by means of value-free evaluations or calculations, but have to be negotiated; therefore, we need politics and discussion to weigh values that in principle cannot be weighed.

(p. 298)

Kolstø’s comment highlights one of the important differences between SSI and earlier attempts to incorporate society and science. Central to the SSI movement is the goal to provide students with the skills necessary for them to negotiate for themselves the science-based issues that they will inevitably be confronted with, if not at a personal level, then as a member of society that will be called upon to make judgements on the technologies (Driver, Newton, & Osborne, 2000; Kolstø, 2006). Socioscientific issues cover a broad range of topics; some of the examples of SSI’s that have been studied in the literature include the applications of biotechnology (Sadler & Zeidler, 2005b), climate change (Topçu et al., 2011), nuclear power (Wu & Tsai, 2007) and other more local issues such as the reintroduction of bears into the Pyrenees (Simonneaux & Simonneaux, 2009). The focus of this current study is on

the applications of biotechnology, and the SSI framework provides an excellent foundation from which to explore the influence of a students' religious beliefs on their attitudes and reasoning about biotechnology because it encompasses not only the science and its effect on society, but also the beliefs and ideologies of the students. In addition, this study, like the SSI movement, is guided by the desire to prepare students for the task of making informed decisions about biotechnology that are consistent with their worldview.

### **2.2.2 Educational Benefits of SSI**

The educational benefits of an SSI-based approach to teaching science have been widely recognised by researchers in this field (Levinson, 2006; Zeidler & Sadler, 2008). Just some of the reasons for implementing an SSI approach include positive impacts on science instruction (Barab, Sadler, Heiselt, Hickey, & Zuiker, 2010), increased understanding of science content (Zohar & Nemet, 2002), improved argumentation skills (Venville & Dawson, 2010), and increased understanding of the nature of science (Khishfe & Lederman, 2006). In addition, Fowler, Zeidler and Sadler (2008) have shown that the use of a SSI framework can improve students' moral reasoning skills about controversial issues. A number of researchers and commentators have called for science education to better equip students in their ability to undertake the task of negotiating the ethical issues associated with biotechnology. These calls have come from science professionals and science educators, as well as religious leaders. Polkinghorne (2000), an accomplished scientist (FRS) and an ordained Anglican priest, commented that:

It is important that society should seek to create forums in which ethical issues can be discussed in truth-seeking and non-confrontational manner. If this prospect of rational debate about biotechnology is to be realised, a considerable educational program will be required. (p.10)

Science education programs that use the socioscientific framework are ideally suited to provide the educational program necessary for students to negotiate the ethically complex world that advances in biotechnology will present to them. For students who come from a Christian religious upbringing or whose own worldview is dominated by a religious faith, then teaching science using a SSI framework provides the possibility for students to approach controversial issues in an environment that acknowledges their core beliefs and recognises that those beliefs will help to shape opinion and behaviour about controversial issues in science.

### **2.2.3 Placement of the Study in the SSI Literature**

The use of contextual frameworks such as science technology society (STS) and the socioscientific issues movement for teaching science was driven largely by a desire to improve the scientific literacy of students and make science more meaningful (Zeidler et al., 2005). As discussed earlier, SSI, while encompassing the attributes of STS, also includes as significant factors the personal beliefs and life experiences of the student. In a critical review of the literature, Zeidler et al. (2005, p. 362) argues “that any view of functional scientific literacy falls short of the mark if it ignores the fundamental factors aimed at promoting the personal cognitive and moral development of students”. Zeidler et al. (2005, p. 361) provides a description of four areas of pedagogical importance that he describes as being “entry points in the science curriculum that can contribute to a student’s personal intellectual development and, in turn, help to inform pedagogy in science education to promote functional scientific literacy.” The four areas were identified as nature of science issues, classroom discourse issues, cultural issues, and case-based issues. This study seeks to add to the current literature in two of these fields of study, namely classroom discourse issues and cultural issues.

#### **2.2.3.1 Classroom Discourse**

Classroom discourse issues broadly refers to the importance of classroom discussion and the development of students’ reasoning and argumentation skills (Zeidler et al., 2005). Science educators have highlighted that the development of students’ scientific literacy would benefit from in-depth interactions between students from a range of cultural viewpoints (Aikenhead, 1985; Driver et al., 2000; Vellom & Anderson, 1999; Zeidler, 1984; Zeidler, Lederman, & Taylor, 1992). The use of informal reasoning by students represents an important aspect of students’ decision-making process about SSI (Kuhn, 1993), and consequentially the classroom discourse that takes place regarding SSI. A small number of studies have examined students’ informal reasoning through different cultural lenses: Topçu’s study involving Turkish pre-service science teachers (Topçu et al., 2011), a study from Taiwan involving high school students (Wu & Tsai, 2007), an Australian study also involving high school students (Dawson & Venville, 2009; Yap, 2012), and an American study (Sadler & Zeidler, 2005a) involving college students. However, cultural differences also exist within a school setting and one of the more obvious

cultural differences amongst secondary students is religious identity. Despite a comprehensive search of the available literature, no studies that compared the informal reasoning of students from the cultural perspective of the Christian faith could be identified.

Research by Levinson (2004) has called into question the ability of classroom science teachers to facilitate student-orientated discussion on SSI without additional support in the form of professional development. Others have also identified the need for support for both teachers and students if they are to learn to reason ethically (Reiss, 2008). It is anticipated that an understanding of how the religious beliefs of students impact on their informal reasoning will contribute to the growing field of research that will enable teachers to be better prepared for discussions about socioscientific issues in their classroom.

#### ***2.2.3.2 Cultural Issues***

The second area of pedagogical importance that this study contributes to is that of cultural issues. Socioscientific issues are controversial for many reasons but this is largely because SSI are so closely entwined with cultural and personal beliefs. While some controversies in science may be the result of insufficient evidence or conflicting priorities, those issues that are least likely to find resolution or meaningful engagement are those where the participants come from different life experiences or hold differing frameworks of understanding (Levinson, 2006). It is therefore important that students and their teachers are able to recognise the critical role that personal identities, including personal experiences and cultural beliefs, play in framing the conflicts inherent in many SSI.

In concluding a discussion about cultural issues, Zeidler et al. (2005) suggests that teachers could be supported in their efforts to engage students in socioscientific issues by providing them with a more detailed understanding of the moral codes and ethical perspectives that result from the cultural diversity of the classroom. This study examines SSI with an eye to the cultural differences represented by students from different religious positions, and it is anticipated that this will go some way at least in providing teachers with a richer understanding of how a students' individual beliefs contribute to their thinking about and overall attitude towards SSI.

## 2.3 ATTITUDES TOWARDS BIOTECHNOLOGY

This section provides a definition of biotechnology, as used in the context of this study, and a theoretical framework for understanding the development of students' attitudes towards biotechnology. The gender differences in attitudes towards biotechnology are briefly discussed, before an in depth exploration of the measurement of biotechnology attitudes is presented, including the limitations of measuring biotechnology attitudes, and a discussion of the key qualities necessary for an instrument that is to be used to measure attitudes towards biotechnology.

### 2.3.1 Definition of Biotechnology

Biotechnology is defined as “The use of plants, animals and micro-organisms to create products or processes...” on the TechNyou website (<http://technyou.education.csiro.au>), an Australian government initiative produced by the CSIRO as a resource for high school science teachers covering the fields of nanotechnology and biotechnology. This resource includes under the banner of biotechnology reproductive technologies such as IVF and pre-implantation genetic testing, forensic techniques such as DNA profiling, applications of stem cell research and cloning, along with more traditional ideas of biotechnology such as selective breeding and the genetic modification of plants and animals. Cook and Fairweather (2005) have noted that in recent years the term has often been used in a more restricted sense to refer to the process of genetically modifying organisms. As previously noted in Chapter 1, in this study the term biotechnology is used with the broad definition that includes GMOs but also incorporates traditional technologies such as the production of cheese as well as the more recent advances involving the manipulation of life such as cloning.

### 2.3.2 Framework for the Development of Attitudes Towards Biotechnology

Attitudes towards biotechnology can be briefly described as the positive or negative feelings about issues involving biotechnology using a common understanding of the term ‘attitude’ (Newhouse, 1990). The study and understanding of attitudes is more complex than this definition implies and has been a dominant research focus for the field of social psychology. The term ‘attitudes’ was first employed in this field of psychology in 1862 by Herbert Spencer (as cited in Ajzen & Fishbein, 1980, p. 13), who suggested that when a person makes a decision regarding a complex issue “much depends on the attitude of mind we preserve while listening to, or taking part

in, the controversy”. From this ‘attitude of mind’ approach grew the early view of attitude, which was defined largely by how it related to behaviour; indeed, it was a basic assumption in much of the early literature that attitude directly determined behaviour. Attitudes were considered to be points on a one-dimensional continuum that explained objects in terms of whether they were good or bad, pleasant or unpleasant. Research centred on how different variables affected the movement of groups on that continuum (Kuhn, 1991). While a lot of valuable research was performed using this framework, it became evident that a one-dimensional approach to attitudes could not explain the many instances where attitude failed to predict behaviour. During the early 1950s, the idea that attitudes are a more multifaceted construct gained support, at least in theory, if not initially in the actual measures of attitude being used by researchers (Ajzen & Fishbein, 1980). This led to the multicomponent view of attitude which was formalised by Rosenberg, Hovland, McGuire, Abelson, and Brehm (1960); in this conceptualisation of attitude the affective, cognitive and behavioural components are considered. Within this framework the attitude towards the object under investigation (biotechnology in the case of the present study), is examined through the trio of cognition, emotion and behavioural intention, such that the corresponding measurable variables would be:

- a) Cognitive: The beliefs, thoughts and previous knowledge about biotechnology
- b) Affective: The feelings and emotions towards biotechnology, including the individual’s anxieties, concerns and fears
- c) Behavioural: The corresponding behaviour of individuals towards the technologies (in this case behavioural intentions are measured as a proxy of the behavioural domain due to the limited opportunities of high school students to demonstrate actual behaviours relevant to biotechnology).

It would be tempting to think that by a simple summation of these three components an accurate measure of attitude towards biotechnology could be obtained. However, the three components are not equally weighted, with some individuals placing more emphasis on the emotive component and others being more concerned with the cognitive or behavioural components. Differences can also occur between the applications of biotechnology, with some technologies, such as cloning, providing a stronger emotive response than others, such as the genetic modification of bacteria (Ajzen & Fishbein, 1980).



Despite not utilising the more contemporary multicomponent approach to attitudes, Ajzen and Fishbein's (1980) theory of reasoned action is valuable to explore how attitudes are formed and influence behaviour. A figure based on Ajzen's model but incorporating the multicomponent model has been presented in Figure 2.2.

Ajzen and Fishbein's (1980) theory follows the traditional model whereby attitudes predict intentions which, largely, determines behaviour. He goes on to suggest that attitudes are determined mostly by beliefs about the object in question and those beliefs are formed by the characteristics, qualities and attributes of that object. When we notice or experience objects that have positive characteristics, we form a belief structure about these objects that determines whether they are good or valuable. This in turn means that we learn to like, that is we have a positive attitude towards, the object. Let's take for example the announcement in 2004 by the Californian-based company Allerca (Hecht, 2004), which planned to produce a genetically modified cat that had spliced out the gene responsible for the production of a common allergen. A student that suffers from cat allergies may find that such a GM cat is a positive characteristic because it allows him to have a pet cat when he was previously unable to. The student would then have positive beliefs about the technology that produced the cat. This in turn would result in positive attitudes towards GM organisms, at least about a GM cat, and hence an increased likelihood that they will indicate an intention to own a genetically modified pet. If circumstances allow, this may have lead him, as did many others, to place a deposit of \$US 250 to secure their own GM cat. Of course the converse scenario of a negative characteristic would form negative beliefs, determining negative attitudes, suggesting negative intentions directing negative behaviour. Ajzen and Fishbein (1980) further note that beliefs can grow and change depending on life experiences; indeed, beliefs are continuously updated, confirmed, or rejected depending on direct observation, outside sources and self-reflection. To continue with our GM cat example, the student may have read the subsequent comment by an asthma and allergic disease expert, reported by New Scientist (Hecht, 2004), that the cat's health may be affected if production of the allergy-responsible protein is blocked. This may cause him to modify his belief about the technology as a result of this new information, instead believing it to be unacceptable to produce a cat that may suffer and thereby changing his attitude about genetically modified cats specifically, and biotechnology in general.

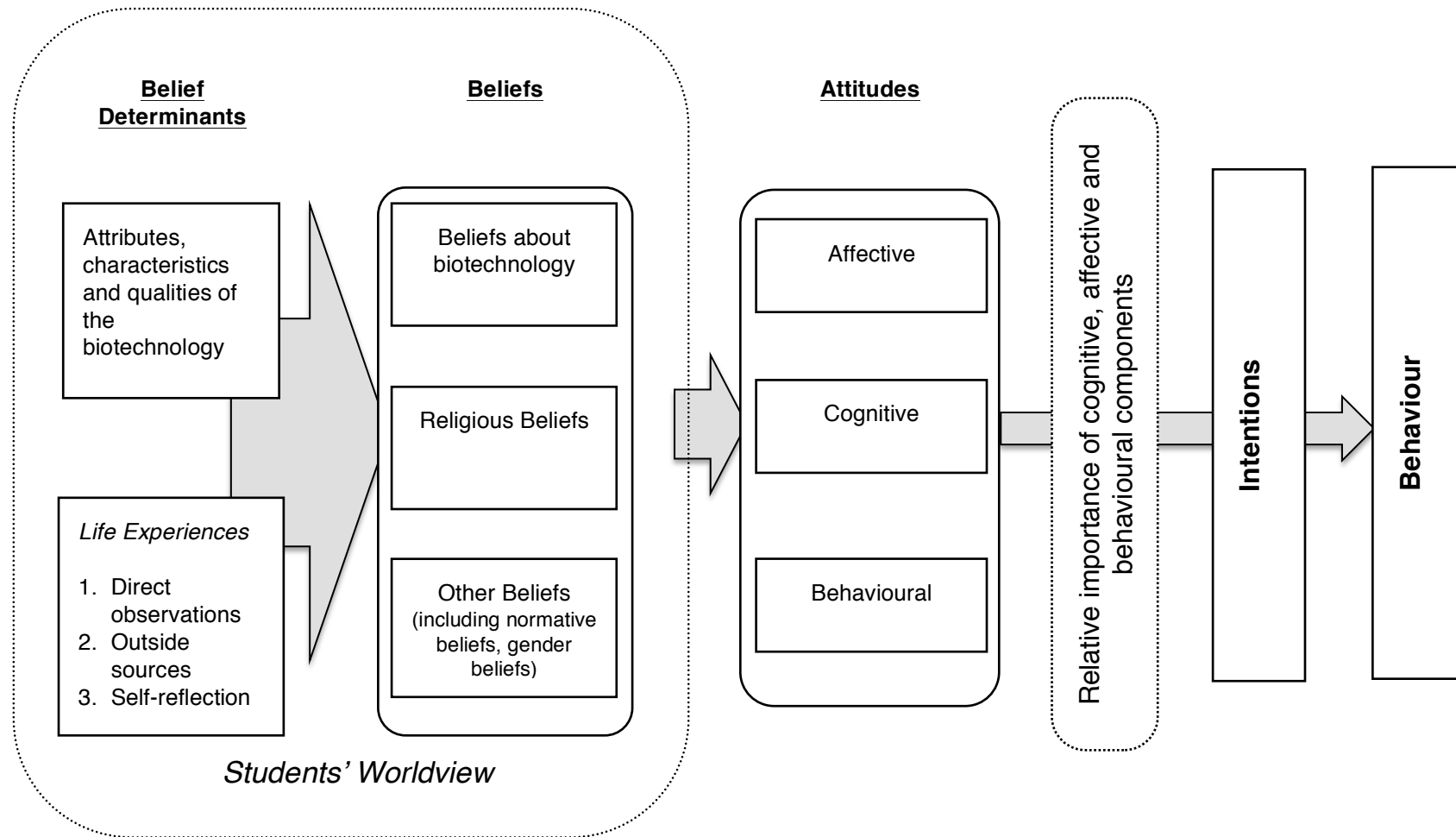


Figure 2.2 *Multicomponent model of behaviour for attitudes towards biotechnology.*

In the complex field of biotechnology, other researchers have demonstrated that preconceived beliefs are especially influential in determining attitude. Scholderer and Frewer (2003) demonstrated that attitudes are determined by more general views held by the student. This is a view that is supported by Cook and Fairweather (2005), who noted a strong link between an individual's worldview and attitudes towards biotechnology.

In attempting to understand students' attitudes, it is important to explore not only the traditional direct measures of attitudes and intentions but also the other components that influence attitudes as indicated by the multicomponent model. These components include what students think about the attributes, characteristics and qualities of biotechnology, their beliefs about biotechnology, and other beliefs, such as religious beliefs, and normative beliefs (those beliefs that an individual perceives that his peers or society think he should believe), all of which may influence the attitudes of the student.

As discussed above, the concept of attitude cannot be taken as a simple one-dimensional construct, nor can it be taken in isolation of many influencing factors. As Kuhn (1991, p. 10) noted, "attitudes can be fully understood only as part of the broader theories that people hold about the world"; it is for this reason that the following definition of attitudes is utilised within this study. Attitudes are perceived as being an internal thought process, which is expressed in an individual's thought, feelings and behaviour (Eagly & Chaiken, 1998).

A study of student attitudes towards biotechnology will provide valuable insight into the acceptance of biotechnology by students. Caution must be taken because, as discussed previously, attitudes towards biotechnology may be difficult to determine, hence any attempt to measure them must consider the many influencing factors involved in attitude formation. Even when attitudes are accurately measured it may not correlate directly as a predictor of behaviour. However, where attitudes are strongly held they tend to be resistant to change and highly predictive of behaviour. An exploration of attitudes provides a partial understanding of how students come to decisions about controversial issues. However, an attempt also needs to be made to understand how students think about these issues; this is the role of informal reasoning in this study.

### **2.3.3 Gender Differences in Attitudes Towards Biotechnology**

Gender differences may also play a role in students' attitudes to biotechnology. A study by Siegrist (1998) examining gender and concerns about biotechnology supported earlier research that has indicated a difference in the attitudes about biotechnology between the genders (Lock & Miles, 1993). Gilligan (1982) has suggested that females have a tendency to assess moral questions as problems of care, involving empathy and compassion. While the strength of her argument may have been weakened with subsequent studies (Jaffee & Hyde, 2000), it is still used as a useful framework for exploring gender differences in moral reasoning. Scientific literacy may also play a role in understanding differences in student attitudes towards biotechnology because of the influence of content knowledge and understanding about the nature of science on students attitudes towards science (Chen & Raffan, 1999; Erdogan, Özel, Uşak, & Prokop, 2009; Lock, Miles, & Hughes, 1995) although this relationship is in no way confirmed with another study showing no relationship (Dawson & Soames, 2006). However while gender differences for scientific literacy are apparent in many countries, as indicated by the PISA 2006 survey, this survey also indicates that in Australia there is no significant difference in overall scientific literacy or in the specific content area of living systems between the genders (Thomson & De Bortoli, 2008).

### **2.3.4 Measuring Biotechnology Attitudes**

Much research has been performed on attitudes to biotechnology and consequently there are a large number of surveys, questionnaires and interview protocols that have been used in an attempt to measure biotechnology attitudes. Similarly the purpose for measuring biotechnology attitudes also varies which has further extended the range of instruments used in this field.

Much of the research over the past two decades has focused on the public understanding of biotechnology. The purpose of these studies has largely been for the benefit of governments and industry, to aid with policy decisions and so that public support for biotechnology can be monitored. The commercial nature of these studies is clearly evident, an example of which is the study by Gunter et al. (1998) which sought to understand teenagers attitudes towards biotechnology so that marketers could better understand how to convince students about the safety of GM food. Davison, Barns, and Schibeci (1997) comment on some of the problems

associated with public opinion surveys about biotechnology that resulted from this industry-driven research.

By and large, they focus narrowly on concerns about health and environmental risks and pass over in virtual silence the broader (and often poorly articulated) public anxieties about the entrenchment of global corporate power and the radical instrumentalization of life that the new biotechnology signifies. (p. 318)

Davison went on to call for more dialogue and a descriptive look at attitudes towards these issues. This increase in dialogue and description can be achieved in two ways. The first is through the use of a mixed methods approach to research that allows students to provide an open-ended expression about their views and concerns. The second is by using an attitudinal scale that is in harmony with the multicomponent view of attitudes and therefore incorporates the affective, cognitive and behavioural components of attitudes towards biotechnology.

In the field of science education, research instruments have been developed that measure attitudes towards biotechnology for a range of purposes. These include an open exploration of students' ideas as future voters (R. Hill, Stanistreet, & Boyes, 2000), teacher awareness for planning and developing programs (Cavanagh et al., 2005; Chen & Raffan, 1999; Kolarova, 2011), intervention programs (Dawson, 2007; Klop, Severiens, Knippels, van Mil, & Ten Dam, 2010), and differences between teachers' and students' attitudes about socioscientific issues (Mohapatra, Priyadarshini, & Biswas, 2010). As many of these studies come out of the STS or SSI framework they tend to provide a better insight into the social concerns of the participants than the industry-driven public opinion surveys.

#### ***2.3.4.1 Limitations of Measuring Biotechnology Attitudes***

Research into attitudes about biotechnology face a number of limitations that impact on the development or selection of an instrument to measure students' attitudes towards this topic. The first two limitations are to do with context. Firstly, the context of the culture that is under investigation, and second, the context of the issue that is being considered. The third limitation reflects the rapidly developing science that is driving the field of biotechnology that makes older instruments less relevant. The final important consideration for an instrument is that it is statistically sound.

#### 2.3.4.1.2 Cultural Context

It has been well documented that attitudes about biotechnology differ substantially across international borders. One of the most publicly reported differences in attitudes about biotechnology is that between Europe and the United States of America regarding attitudes towards genetically engineered food. Research that focuses on these two populations has consistently shown that US citizens are more favourable to GM food products than populations from across the Atlantic (Gaskell, Bauer, Durant, & Allum, 1999; H. Peters, Lang, Sawicka, & Hallman, 2007). Other cross cultural differences have also been observed (Ziman, 1980), and for this reason much of the research, including that within the field of science education, has been repeated around the globe, including research in Europe (Gunter et al., 1998; R. Hill et al., 2000; Klop, 2008), Turkey (Özel, Erdogan, Usak, & Prokop, 2009), Taiwan (Chen & Raffan, 1999), Australia (Cavanagh et al., 2005; Dawson, 2007), as well as many other countries and cultural groups. Very few studies, however, have examined cultural differences within a region or a school.

#### 2.3.4.1.3 Issue Context

A number of researchers have explored how students' attitude about socioscientific issues in general, and biotechnology in particular, are dependent on the issue that is under investigation (Chen & Raffan, 1999; Dawson & Soames, 2006; Gunter et al., 1998; Özel et al., 2009). These authors have described a trend in students' attitudes towards biotechnology application that moves from widespread acceptance of biotechnology involving bacteria, and to a lesser extent plants, to an increasing level of concern about technologies involving animals, and the most concern over applications that involve humans. This observed phyletic trend is likely a reflection of deeper held values, and processes of risk assessment that are determined by cultural and historical factors (Saez, Nino, & Carretero, 2008). Not all studies have shown such a clear trend dependent on the phylum or species of the organisms involved (Luján & Todt, 2000; Özel et al., 2009). Cultural issues are likely playing a significant role in these two studies, where individuals express a greater concern over genetically modified food than some medical interventions.

As presented in the multicomponent model earlier in this section, students' attitudes about biotechnology are developed out of their worldview, which include core beliefs such as religious beliefs and normative beliefs. These beliefs will be

manifested in different ways as they compete with each other to shape the students' overall attitude about the technology. Different issues will likely cause students to draw, to a greater or lesser extent, upon those beliefs central to their faith than other applications of biotechnology. For example, when considering the bioengineering of plants, a student may have to weigh up the benefits of increased food production with religious beliefs about the role of God in creation. While this may be a significant theological obstacle for the individual it is unlikely to play as large a role as those issues that involve core religious beliefs about the humanity of embryos. As the aims of this present study are to further understand the thinking and attitudes of students from differing religious backgrounds, it will be essential to track how the students' attitudes change over a range of biotechnology applications. Many of the instruments used to measure students' attitudes towards biotechnology examine only a narrow range of applications to biotechnology, often focusing on just a single issue, such as genetically modified organisms (Herodotou et al., 2011) or food production (Gunter et al., 1998). While this may be of value for some research, the context of this study calls for a broader range of biotechnology applications to be examined for a more complete understanding of student attitudes towards biotechnology.

#### 2.3.4.1.4 Inclusion of Modern Advances in Biotechnology

The third consideration in looking for a suitable instrument to measure students' attitudes towards biotechnology is whether it is inclusive of modern developments in the field of biotechnology. As scientists develop new techniques for manipulating living systems, they raise new ethical dilemmas and reframe old controversies. One such breakthrough was somatic cell nuclear transfer (SCNT), which opened up a range of new applications for biotechnology. More recent instruments measuring students' attitudes to biotechnology reflect the changing face of biotechnology with their inclusion of such techniques as cloning (Erdogan et al., 2009), pre-implantation genetic screening, and recent applications of stem cells (Fonseca, Costa, Lencastre, & Tavares, 2013). In contrast, research around the turn of the century was still very much focused on a subset of biotechnology that included the genetic engineering of plants and animals (Cavanagh et al., 2005; Gunter et al., 1998; Lock & Miles, 1993; Siegrist, 1998).

#### 2.3.4.1.5 Statistical Integrity

The final consideration for an instrument to measure students' attitudes about biotechnology is whether the instrument has been constructed according to standard statistical techniques and appropriately validated. In a review of the literature, Fonseca et al. (2013) noted that while there were many studies researching students attitudes towards biotechnology, there was no consistency in the instruments being used and, with a few notable exceptions (Erdogan et al., 2009; Klop & Severiens, 2007), many of the questionnaires used did not provided a statistically sound measure of students' attitudes towards biotechnology. Associated with the instrument design is the observation made by Luján and Todt (2000) that the opinions of individuals may differ depending on the type of questions posed in the questionnaire. These authors showed that general valuations provide different responses to those obtained about attitudes on research, which again differs from opinions on specific applications. For this reason a range of questions are required to adequately assess students' attitudes towards biotechnology.

#### 2.3.4.2 ***Qualities of an Instrument to Measure Biotechnology Attitudes***

In summary, of the literature on attitudes towards biotechnology scales presented above, the characteristics necessary for an instrument to measure students' attitudes towards biotechnology are that the questionnaire:

1. Incorporates the affective, cognitive and behavioural components of attitude;
2. Provides an opportunity for students to provide open-ended responses to issues;
3. Includes a range of biotechnology applications, including those from more recent advances in science;
4. Provides the ability to make comparisons with other studies; and
5. Is constructed and validated using standard statistical procedures.

The instrument constructed by Klop (2008) to measure high school students' attitudes towards biotechnology was developed using Ajzen and Fishbein's (1980) model of attitudes and also used a rigorous statistical process to develop and validate the questionnaire. However, a number of issues remain with this questionnaire. Firstly, the questionnaire was conducted in Dutch and would require translation and modification for the current context in Australian high school students. Secondly, this questionnaire would require updating to incorporate students' concerns about more recent technology such as cloning and pre-implantation genetic screening.



Finally, the questionnaire does not include the opportunity for students to provide written responses to a range of biotechnology applications.

## 2.4 INFORMAL REASONING

This section provides a discussion about informal reasoning and examines some of the recent research in this field. A definition of informal reasoning is provided, followed by a look at some of the different approaches to informal reasoning that has been used by researchers in the past. Patterns of informal reasoning, the informal reasoning classification system used in this study, are further explored, including a description of rational, emotive and intuitive informal reasoning. Five recent studies that have used patterns of informal reasoning to examine students' thinking about biotechnology are reviewed and the context and relevant findings of these studies are discussed. The role of issue and cultural context in informal reasoning is also discussed, before the section concludes with a look at the limited number of studies that have investigated reasoning within the context of religious and non-religious worldviews.

### 2.4.1 Definition of Informal Reasoning

When faced with any problem, students must use their reasoning skills to come up with a solution. This broad term refers to the thought processes that a student undertakes to obtain a conclusion. In a secondary school environment, students are frequently required to utilise reasoning to solve well-structured problems in domain-specific areas such as mathematical problems and analysing experimental data in science (Brickell, Ferry, & Harper, 2002). Reasoning is also used at a more basic level when deciding what clothes to wear, or even what flavoured ice cream to buy. Some problems, such as those associated with many aspects of biotechnology, can get very complicated, with multiple lines of evidence for, or against, a given position.

It is important to note that reasoning is related to but distinct from argumentation, which is a process of presenting a convincing case for a given position (Means & Voss, 1996). Socioscientific issues, those issues that are scientific in nature but which have a social implication (Zeidler et al., 2005), require students to undergo a reasoning process to determine the position that they will take on the issue.

This process is called informal reasoning and differs from formal reasoning in the following ways. Formal reasoning consists of having one or a number of premises

and not adding anything to them throughout the argument. Formal reasoning then proceeds in logical (deductive) steps until a conclusion is obtained. Using this process and provided that the premises are consistent, only one side of the argument needs to be examined. Such reasoning is often described as proofs, and examples would be the derivation of mathematical problems. Informal reasoning is performed very differently. Premises may be included or removed as new information becomes available or as the initial premises are reviewed. Also, informal reasoning must assess arguments, some of which provide support for one position while others add weight to an alternative perspective (Perkins, Faraday, & Bushey, 1991). When these differences are compared, it becomes obvious that informal reasoning is necessary in a field like biotechnology where individuals are rarely provided with all of the relevant information but instead must contend with partial and sometimes conflicting data that needs to be incorporated into the reasoning process.

As has been noted in the previous section discussing students' attitudes about biotechnology, what a student ends up concluding about the merits or appropriateness regarding the use of biotechnology comes out of the students' worldview, which includes the individual's beliefs, such as beliefs about biotechnology, religious beliefs, and other beliefs (including, but not limited to, normative beliefs and gender beliefs). From these beliefs comes a student's attitude about biotechnology and, ultimately, their intentions and behaviour. This process of moving from beliefs, sometimes consciously held and sometimes not, to intentions and behaviour is encapsulated in the process of informal reasoning. In this context then, informal reasoning can be described as the thought process that a student undergoes as they move from left to right of the multicomponent model previously presented in Figure 2.2.

#### **2.4.2 Approaches to Informal Reasoning**

Different approaches have been taken by researchers to measure and classify students' informal reasoning. One approach that is used by many researchers to explore informal reasoning is argumentation (Dawson & Venville, 2009; Topçu, 2010; Venville & Dawson, 2010). This approach allows for a measure of quality to be given to the students reasoning but does not allow for a descriptive classification of the type of thinking that the student is undertaking. Previous research investigating informal reasoning as argument (Kuhn, 1993), classified students

informal reasoning in terms of the way that individuals used evidence to substantiate their claims. This classification provided an insight into students' scientific thinking in the process of informal reasoning but did not consider thought processes that might be more common outside of scientific domain.

Another approach, taken by Yang and Anderson (2003), used a classification system of scientifically oriented, socially oriented and equally disposed reasoning to differentiate those students who made decisions based predominantly on scientific factors from those who utilised predominantly social factors. One of the limitations of this approach is that it does not differentiate between reasoning that is based on a rational approach that identifies facts and makes logical conclusions, and reasoning that is based only on the individual's opinions or feelings.

A third approach to investigate informal reasoning was proposed by Sadler and Zeidler (2005a), who identified patterns of informal reasoning. This approach recognises that students may have specific knowledge, of the subjects that they incorporate into their reasoning and use it in a logical and systematic process. This was termed 'rational informal reasoning'. Instead of using arguments based on facts and specific knowledge students sometimes use 'gut feelings' in explaining their conclusion. This type of reasoning was described as intuitive reasoning. Sadler and Zeidler (2005a) also identified students who utilise reasoning based on emotion, typically referred to as affective reasoning, to support or replace cognitive reasoning. Sadler and Zeidler (2005a) were clear to point out that empathetic informal reasoning differed from rational informal reasoning in that it utilised a care-for-others approach that rational reasoning did not, and it differed from intuitive reasoning by focusing on the care and feelings of others rather than the feeling and emotions of the respondent. Sadler and Zeidler (2005a) also noted that the emotive reasoning they observed was often cognitively equivalent to the rational mode of reasoning in terms of its logical construction. Sadler and Zeidler (2005b) point out that in this way it differs from the Kohlbergian view of emotive reasoning, which considers emotive reasoning to be a less developed mode of moral decision-making. These authors go on to suggest that:

Furthermore, we as educators have no empirical basis for the belief that negotiating SSI from a rationalistic perspective results in higher quality

reasoning (at least defined in terms of the criteria outlined in this study) than emotive or intuitive perspectives. (p. 89)

Sadler and Zeidler (2005b) come to this conclusion from a philosophical perspective grounded in critical theory. However, the suggestion that rational informal reasoning holds no superior place over intuitive and possibly even emotive reasoning has not gone unquestioned in the literature. Hodson (2003) points out that the equal status of rational, emotive and intuitive informal reasoning is not consistent with a traditional view of science and science education, which emphasises rational patterns of reasoning over others (Zohar & Nemet, 2002); the authors do not, however, make it clear whether they believe that the three modes of informal reasoning should be given equal status or not. In contrast, Dawson and Venville (2009) contend that rational reasoning is a central component of scientific literacy. While acknowledging the importance of emotive reasoning, Dawson and Venville (2009) use Trowbridge and Bybee's (1997) definitions of scientific literacy to argue that:

Scientific literacy requires at least some scientific knowledge or conceptual scheme, and this would require the students to have demonstrated some form of rational informal reasoning. (p. 1440)

These concerns may be of limited significance as research on belief bias has suggested that students may unconsciously make a decision about issues first and then find reasons to justify that decision (Jonathan Evans, 1996; Evans & Curtis-Holmes, 2005; V. Thompson & Evans, 2012; Wu & Tsai, 2010). If this is the case then it may, at least on a practical level, reduce the significance of rational informal reasoning as a unique characteristic of science literacy because students are not necessarily using this reasoning process in a way that would be expected from a truly scientific methodology; for example, reserving judgement until the facts have been assessed.

When assessing the appropriateness of a biotechnological process, the three modes of informal reasoning - rational, emotional and intuitive (referred here collectively as patterns of informal reasoning) - are often combined in various ways to come to a conclusion. A number of other researchers have utilised Sadlers' patterns of informal reasoning to explore socioscientific issues involving biotechnology (Dawson & Venville, 2009; Sadler & Zeidler, 2005a; Topçu et al., 2011; van der Zande et al., 2009; Yap, 2012). The informal reasoning used by students is unlikely to follow the same pattern for every scenario. It has been shown that an increase in students'

understanding about socioscientific issues results in higher quality reasoning (Lewis & Leach, 2006; Sadler & Fowler, 2006; Sadler & Zeidler, 2005b; Topçu, Sadler, & Yilmaz, 2010; Tytler, 2001). This is often measured in the level of argumentation, which, as discussed earlier, differs from patterns of informal reasoning, which examines the types of thinking used to come to conclusions, rather than the sophistication of the argument. It could still be reasonably postulated that students with a low level of understanding about a topic will imply more non-rational modes in their decision-making. A study by Sadler and Zeidler (2005b) did not find a link between content knowledge and patterns of informal reasoning; however, it did not rule out that such a link existed. Because of the nature of socioscientific issues, it is likely that students' patterns of informal reasoning may change when they are asked to assess different socioscientific issues. For example, those issues that challenge the strongly held religious beliefs, such as the human status of an embryo, may influence the patterns of informal reasoning used by those students. No research could be found that explored this idea further. However, it would not be surprising to observe differences in the patterns of informal reasoning not only between different ethical dilemmas but also between religious and non-religious students.

#### **2.4.3 Patterns of Informal Reasoning in Biotechnology**

A number of studies have used biotechnology as the source for socioscientific issues from which to explore patterns of informal reasoning. A summary of these studies can be found in Table 2.1, which shows the education level of the students, number of participants, country in which the study was undertaken, biotechnology issues addressed in the study and the percentage of rational, emotive and intuitive informal reasoning identified in the study. The context of each study, along with a discussion of the study's relevance to this thesis, has been provided.

##### ***2.4.3.1 Context of Studies Researching Patterns of Informal Reasoning***

Sadler's US study (Sadler & Zeidler, 2005a, 2005b) examined 15 college students' patterns of informal reasoning and focused on the issues of human cloning, both therapeutic and reproductive, as well as gene therapy. Dawson's Australian study (Dawson & Venville, 2009) included a wider range of biotechnology issues including different aspects of GM foods, cloning, and genetic testing. Thirty secondary students participated in the study and included Year 8, 10 and 12 students with typical ages in Australia ranging from 12-18 for those year levels.

Table 2.1 *Studies of Informal Reasoning in Biotechnology Showing Educational Level, Number and Country of Participants, Biotechnology Issues Addressed, and Percentage of Each Mode of Reasoning*

Study	Level	n	Country	Biotechnology addressed	% of informal reasoning used		
					Rational	Emotive	Intuitive
Sadler and Zeidler (2005a, 2005b)	University students	30	USA	Gene therapy Reproductive cloning Therapeutic cloning	88	47	25
Dawson and Venville (2009)	High School students 13-18 years of age	30	Australia	GM Foods cloning genetic testing	26	35	36
van der Zande et al. (2009)	High School Students 14-15 years of age	15	Netherlands	Pre-natal testing Genetic screening	100	100	100
Topçu et al. (2010)	University students (Pre-service science teachers)	39	Turkey	Gene Therapy Reproductive cloning Therapeutic cloning	60	28	24
Yap (2012)	High School Students 15-17 years of age	63	Australia	GM food Pre-implantation genetic screening Reproductive cloning Therapeutic cloning	18	6	30

In a Dutch study van der Zande et al. (2009) investigated 15 students who were between 14 and 15 years of age and dealt with the issues of pre-natal testing and genetic screening. The second Australian study (Yap, 2012) included 63 students in either Year 10 or Year 11 (typically between 15-17 years of age) and examined GM food, pre-embryotic genetic screening, reproductive cloning and therapeutic cloning. The final study was from Turkey (Topçu et al., 2011) and involved 39 pre-service teachers who examined the issues of human cloning (reproductive and therapeutic), gene therapy and global warming.

#### **2.4.3.2 Discussion of Studies Researching Patterns of Informal Reasoning**

A summary of the results obtained in each study with regard to the frequency with which students used the modes of informal reasoning is shown in Table 2.1 While all of the studies utilised the three modes of informal reasoning, rational, emotive and intuitive, there are significant differences in the procedures such that it is very difficult to make direct comparisons between the five. Yap's (2012) study, which was investigating the use of ethical frameworks, included a fourth mode which she entitled 'moral reasoning'. In addition, Yap (2012) classified students' reasoning based on their overall use of four modes of reasoning rather than identifying the informal reasoning of each statement. The Dutch study (van der Zande et al., 2009) utilised a broader definition of emotive reasoning that included the basic emotions such as fear, anger, joy and surprise. van der Zande et al. (2009, p. 35) questioned the distinction made between intuitive and emotive reasoning, noting "neither the students nor the teachers conceptually made clear distinction between emotive and intuitive reasoning". His broader notion of intuitive reasoning by including *prima facie* duties such as fidelity, justice, gratitude, beneficence and non-injury was justified with the notion that for secondary school students such duties would not yet be self-evident as they only become so when an individual reaches a sufficient mental maturity. It is possible that this broadening of the definition for intuitive reasoning blurred the differences between the intuitive and emotive domains which Sadler and Zeidler's (2005a) research supported as being distinct methods of reasoning.

In the first study to use this classification of informal reasoning Sadler and Zeidler (2005a) found that all students utilised rationalistic informal reasoning in at least one of their responses, with a total of 88% of responses incorporating this mode of

reasoning. Emotional reasoning was used by almost half of the participants (47% of responses), and intuitive reasoning was incorporated into the least number of responses (25%). In Topçu's (2011) study, which also involved university students, rational informal reasoning was the predominant reasoning used, with emotive and intuitive used less than rational but with similar frequency to each other.

The two Australian studies, which looked at secondary students, showed a distinct difference in the informal reasoning patterns, with rational reasoning being used less often than intuitive reasoning and emotive reasoning being the least used mode. It was suggested by Dawson and Venville (2009) that these differences are likely the result of increased education and life experiences and were consistent with Sadler's (2005b) proposal for a threshold of content knowledge transfer.

Because of the differences in terminology, the Dutch study cannot be directly compared; however, van der Zande et al. (2009) was able to demonstrate that students' perceived use of informal reasoning did not match their actual use. When the researchers measured the students' patterns of informal reasoning it was shown that they utilised all three of the modes; however, students self-reported that they did not use any intuitive reasoning. This highlights the low level of student awareness about their own reasoning practices and, when considered alongside the research by Dawson and Venville (2009) and Yap (2012), whose findings showed an increased use of intuitive and low levels of rational informal reasoning, it supports the notion presented by all of the authors that science education needs to encourage students to be more aware of their modes of reasoning in socioscientific issues, so that a balance can be maintained.

While all five of the researchers encouraged the use of all modes of reasoning, Kuhn (1991) points out that intuition is the default position that people come to before rationalising their arguments. Van der Zande et al. (2009) used this concept to emphasise the need to actively teach intuitive and emotional reasoning in moral education. With their broader definition of intuitive reasoning, van der Zande et al. (2009) gave a more significant role to the influence of emotions as a foundation for intuition than some of the other authors, and yet all authors recognised the importance of emotion in the moral reasoning process. The need for interaction between the three domains is clearly important, especially when consideration is



made that some intuition and emotion is based on prejudice and requires rational scrutiny (Lester. Hunt, 2006). In addition, it could be suggested that some rational reasoning would benefit from the moderating effects of emotions.

#### **2.4.4 Issue and Cultural Context in Patterns of Informal Reasoning**

The Turkish studies (Topçu et al., 2010; Topçu et al., 2011) specifically set out to determine if the context of the issue, for example, different SSIs, had an influence on students' quality and patterns of informal reasoning. Working from research, such as Lewis and Leach (2006) and Sadler and Fowler (2006), which document a significant link between informal reasoning and content understanding, Topçu et al. (2011) proposed that students' patterns of informal reasoning would be context-dependent because students' content knowledge would vary across the scenarios. Topçu et al. (2010) and Topçu et al. (2011) were able to find a statistically significant difference in university students' quality of informal reasoning as well as differences in the patterns of informal reasoning. They found that, in general, intuitive reasoning was notably more frequent amongst discussion regarding cloning and global warming. The research from these two papers (Topçu et al., 2010; Topçu et al., 2011) also provides an insight into the informal reasoning of students who are culturally very different from many other studies. The authors describe the students in their study as coming predominantly from a Muslim religious tradition. When compared to the American study, the authors were unable to find any major differences in students' informal reasoning between the two culturally distinct groups. The Australian study by Yap (2012) was set in an evangelical Christian college where the students demonstrated less emotive reasoning than the students in the other Australian study by Dawson and Venville (2009). It is not possible, however, to make any comparisons between the two groups in terms of the effects of religious belief on students' patterns of informal reasoning, as the Dawson and Venville (2009) study had no measure of the religious beliefs of the students and the sample size of both also makes comparisons difficult. A comprehensive review of the current research was unable to locate any other studies within an educational setting that could be used to compare the informal reasoning of culturally distinct groups characterised by differences in religious belief.

#### **2.4.5 Informal Reasoning and Religious Belief**

Outside of the field of educational research, a number of studies provide insight into patterns of informal reasoning. One such study (Shenhav et al., 2012) provides evidence to suggest that people who have a belief in God are associated with an increased use of intuitive thinking processes compared with non-believers. More specifically, the authors make a case that individuals who are drawn to an intuitive cognitive style are more likely to have, and develop over time, their belief in God. Their study also showed that while intuitive reasoning was a predictor of an individual's religious belief since childhood, it was not associated with their religious beliefs of childhood. While this strengthens the author's claims about the role of intuitive reasoning and belief in God, it highlights the difficulty in observing associations between intuitive reasoning and religious beliefs in the context of this study, which is focused on high school students who are still transitioning from their childhood beliefs, dominated by parents and their faith communities, into their own personal religious belief systems.

Another study, which also supported the link between intuitive reasoning and belief in God, provides evidence for the decreased use of rational thinking processes amongst those who believe in God (Aarnio & Lindeman, 2007). The authors note that the relationship between believers and rational modes of reason was not a strong one. The same study also supported other studies (Roccas, Sagiv, Schwartz, & Knafo, 2002; Saroglou, Delpierre, & Dernelle, 2004) that suggest religious believers valued self-transcendence (benevolence) more than religious sceptics. A higher value on benevolence may translate into an increase in the use of emotive reasoning, although these studies neither measured that mode of informal reasoning nor made reference to any possible connection. Looking more specifically at emotive reasoning, earlier research by Francis and Pearson (1987) suggests that adolescent religiosity was positively correlated with empathy. This is still not emotive reasoning, although it would be expected that a student demonstrating more empathy would be more inclined to use emotive reasoning. Regardless of this distinction, more recent research (Duriez, 2004; Watson, Hood, Morris, & Hall, 1984) has suggested that it is the attitude and approach to religion that are better predictors of measures of empathy and emotional intelligence than religiosity itself. Individuals with an internalised and more symbolic approach to religion were more likely to demonstrate

empathy and care. Although this research on patterns of informal reasoning has yet to be completed, it would be reasonable to conclude from the circumstantial evidence presented here that students with a higher level of Christian religious belief would use less rational, more emotive, and more intuitive informal reasoning than their less religious peers.

## 2.5 MORAL JUDGEMENT AND CHRISTIAN WORLDVIEWS

This section provides a review of the literature on moral judgement and Christian worldviews. It starts by defining moral judgement and highlights the role that worldview plays in the process of ethical decision-making. The concept of worldview is then elucidated and the four key aspects of the resulting definition are discussed: worldview is culturally organised, worldview influences the way that individuals think about an issue, a worldview defines what an individual describes as self, and an individual's worldview is constructed through physical and social interactions. The final two parts of this section address the Christian worldview: the first outlines what constitutes a Christian worldview and highlights some of the diversity that exists within that term, while the second suggests a framework for the measurement of Christian worldviews.

### 2.5.1 Definition of Moral Reasoning

Because of the nature of socioscientific issues, it is likely that two students may come to opposing conclusions about the application of a given biotechnology. Although sound reasoning, the use of established ethical frameworks and a general consensus will increase the confidence that an ethical decision is valid (Reiss, 1999), such conclusions are ultimately moral judgements that are the result of conscious thought and that reflect the individual's notion of right and wrong (Haidt, 2001). A useful definition for moral judgements is provided by Haidt (2001).

*Moral judgments* are therefore defined as evaluations (good vs. bad) of the actions or character of a person that are made with respect to a set of virtues held to be obligatory by a culture or subculture. (p. 817)

As in the definitions used for moral judgements by other researchers (Audi, 1999; Frewer & Shepherd, 1995), this definition highlights the important role that the cultural group has in the determining of right and wrong.

Previous research has suggested that these decisions may be based on intrinsic or extrinsic concerns (Evensen et al., 2000; Frewer & Shepherd, 1995). Intrinsic

objections, sometimes referred to as deontological objections, are concerns about the nature of the technology itself. Extrinsic or, as they are sometimes called, consequential concerns, focus on the consequences that the technology might have on individuals, communities or the environment. Both intrinsic and extrinsic concerns will help guide an individual to a decision about the technology under investigation. However, at least three studies have shown that intrinsic concerns are more influential in moral decision-making (Dragojlovic & Einsiedel, 2013; Macer, 1994; Reiss & Straughan, 1996). This is a reasonable conclusion because, if a particular technology is considered intrinsically wrong, then the consequences of such an action are morally irrelevant when compared to the intrinsic wrongness of the actual technology. Intrinsic concerns are a product of an individual's worldview. Indeed, extrinsic concerns may also arise from an individual's worldview, or more specifically, the weight that is given to those consequences would reflect the a priori beliefs of an individual's worldview. Ultimately, all moral values and attitudes can be traced back to an individual's worldview (John Evans, 1997; Hunter, 1991).

### **2.5.2 Worldview**

The concept of worldview, in its simplest form, is a collection of presuppositions that describe for an individual what the world is really like. In doing so, it provides that individual with the foundations for thought, emotion and behaviour (Cobern, 1996). Most people do not think much about their worldview, and some may never stop to think about the presuppositions that govern their lives. Despite this, an understanding of worldviews is an essential undertaking for anyone interested in attitudes and reasoning about socioscientific issues (Evensen et al., 2000).

The term, 'worldview', has its origins in the German word *Weltanschauung* and was introduced to Western philosophy by Immanuel Kant (Naugle, 2002; Sire, 2004) and the concept developed in the anthropological study of culture. Research by Benedict (1935) and Pepper (1942) focused on comparing worldviews by identifying the themes that were representative of a worldview. A theoretical framework for the concept of worldview was presented by the cultural anthropologist Kearney (1984) who provided the following definition.

...culturally organized macro thought: those dynamically inter-related basic assumptions of a people that determine much of their behaviour and decision

making, as well as organizing much of their body of symbolic creations ... and ethnophilosophy in general. (p. 1)

Four important ideas help to conceptualise the idea of worldview as used in this research and highlighted by Kearney's definition. Worldview is culturally organised, influences the way that individuals think about an issue, defines what an individual describes as self, and is constructed through physical and social interactions.

#### **2.5.2.1 *Worldview and Culture***

That culture is closely aligned with the worldview of individuals is self-evident, given the origins of the anthropological worldview construct. The concept of culture is described by (Geertz, 1973, p. 89) as

...an historically transmitted pattern of meanings embodied in symbols, a system of inherited conceptions expressed in symbolic forms by means of which men communicate, perpetuate, and develop their knowledge about and attitudes toward life.

It is therefore through these 'transmitted patterns of reasoning' and 'inherited conceptions' that the worldview of individuals within a culture is formed. Religion, including Christian religious belief and a Christian worldview, which is the subject of this research, sits comfortably within this definition of culture, such that religious beliefs and practices provide for the group a worldview that describes what they believe to be reality (Geertz, 1973). Even though that group has its own set of presuppositions that are collectively shared, much more is meant than simply the culture of his or her group when referring to an individual's worldview. In this way it is possible to talk of an individual who has a Christian religious worldview as being a member of a cultural group that shares core beliefs about the nature of reality, but who also has their own worldview that encompasses their own personal ideas and beliefs.

#### **2.5.2.2 *Worldview and Reasoning***

Worldview influences the way that individuals think about an issue. To reason means to have a sound explanation or justification for thought and action, and yet the explanations and justifications that an individual makes are going to depend on the presuppositions of the individual or group's worldview (Cobern, 1996). Kearney (1984, p. 41) describes worldview as providing a "more or less coherent, though not necessarily accurate, way of thinking about the world". The influence of worldview

on reasoning is most evident in the debate over creation and evolution, a result of the conflict between a scientific worldview and a religious worldview. In a discussion of the importance of understanding worldviews in science education, Cobern (1996) suggests that the term ‘scientific worldview’ is misleading because worldview describes so much more than the realm of science. He suggests the alternative of ‘scientifically compatible’ worldview. An individual with a scientifically compatible worldview would find the arguments of a young earth creationist nonsensical. However, from the perspective of a Christian worldview or, more accurately, a fundamentalist evangelical subset of the Christian worldview, presupposition regarding biblical interpretation provides a rational justification (from the perspective of the reasoner) for the rejection of evolutionary theory. Ultimately, if the fundamentalist faces a choice between science and the accepted dogma of his or her faith tradition, science will lose every time (P. Thompson, 1993).

#### **2.5.2.3 *Worldview Defines Self***

A worldview defines what an individual describes as self. Cobern (1997) aptly describes this relationship between worldview and self.

It sets the boundaries of who and what I am. It also defines everything that is not me, including my relationships to the human and non-human environments. It shapes my view of the universe, my conception of time and of space. It influences my norms and values. (p. 2)

#### **2.5.2.4 *Construction of Worldviews***

An individual’s worldview is constructed through physical and social interactions. This process of building up presuppositions occurs throughout a lifetime but is most significant in the years associated with formal education (Cobern, 1997). A number of researchers agree that one of the primary purposes of education is to provide an opportunity for the examination and transformation of worldviews (Cobern, 1996, 1997; Duschl, 1991; R. S. Peters, 1975). Because of the way that the socioscientific issues movement draws upon culture, including a religious understanding of controversial issues in science, it provides an opportunity for students to examine the presuppositions and cultural norms that are inherent in their worldview. As SSI are explored, the interactions that an individual has between their peers, their teachers, and the wider community may play an important role in shaping an individual’s worldview. The power of social interactions in shaping an individual worldview is emphasised by Haidt (2001):

Because people are highly attuned to the emergence of group norms, the model proposes that the mere fact that friends, allies, and acquaintances have made a moral judgment exerts a direct influence on others, even if no reasoned persuasion is used. Such social forces may elicit only outward conformity, but in many cases people's privately held judgments are directly shaped by the judgments of others. (p. 7)

Family networks are also an important contributor for worldview development, with research by Scheepers and Slik (1998) emphasising the role of parents and spouses in determining an individual's moral attitudes. An appreciation of the role that formal schooling can have in shaping a student's worldview should give science educators reason to pause. As figures of authority within the classroom, there is significant opportunity to influence the development of a students' worldview; however, this also comes with a responsibility to respect the cultural values of the group so as to minimise the harm that dissonance within the students' worldview may bring.

### **2.5.3 Christian Worldviews**

Any description of a Christian worldview is problematic; the difficulties lie in the diversity of beliefs and biblical interpretations that exist within the Christian tradition. One starting place for an insight into the nature of a Christian worldview is to examine the definition of worldview given by an author from within the Christian tradition. Sire (2004), writing as a Christian believer, included as his definition of worldview:

A worldview is a commitment, a fundamental orientation of the heart that can be expressed as a story or in a set of prepositions which we hold about the basic constitution of reality, and that provides the foundation on which we live and move and have our being. (p. 122)

Like earlier definitions, this one by Sire includes reference to presuppositions that describe reality. However, for the Christian believer, worldview is more than this, and the language of this definition emphasises the commitment and orientation of the individual. There seems to be a sense of duty and purposefulness within the Christian description of worldview, which is the result of presuppositions that provide a greater weight on how we should live. This is a concept that is absent in secular definitions of worldview. The term 'Christian worldview' appears to be used more to describe what one must believe and do to be a Christian, rather than an anthropological description of a group of people.

Regardless of what Christian tradition an individual adheres to, most would agree that central to the Christian worldview is the belief in God and His ongoing involvement in the world, the central role of Jesus Christ of Nazareth, and the Bible as the ultimate source for understanding reality (Dockery, Thornbury, & Colson, 2002; Goheen & Bartholomew, 2008; Naugle, 2002; Sire, 2004). Furthermore, Orr (1893, p. 40) suggests that “[i]t is the fundamental assumption.... that the central point in the Christian view of God and the world is the acknowledgment of Jesus Christ as a truly Divine Person—the Son of God made flesh.”

The role of the Bible as a source of knowledge has a significant role in shaping Christian worldviews.

“If we truly believe that the Bible is God’s Word to us, the true story of the world, it is clear that our worldview must be rooted and grounded there.” (Goheen & Bartholomew, 2008, p. 31)

Like all religious texts, the Bible must be interpreted, and it is here that many of the differences between Christian denominations, and therefore different forms of the Christian worldview, arise. Protestant Christian believers are often divided into three broad categories: Fundamentalist, Evangelical and Liberal Christians. Many researchers consider fundamentalist as a more conservative subset of evangelicalism, as they share many of the same core theological beliefs (Hackett & Lindsay, 2008; Mead, 2008; Smidt, 1988). In a review of research that studied the evangelical movement, Hackett and Lindsay (2008) identified a drastically different picture of evangelicals, depending on how the researchers defined the term. Care therefore needs to be taken when reading the literature that uses the description ‘evangelical’. While researchers may differentiate between these groups as a convenient method to study them, the actual distinctions between the groups are not clear. It is more accurate to speak of a spectrum of Christian worldviews, one that ranges from a Fundamentalist Christian worldview, to a mainstream Evangelical worldview, and finally to a Liberal Christian worldview. Broadly speaking, this spectrum can be aligned with views on biblical interpretation. Fundamentalist Christians take a more literal interpretation of scripture, typically associated with anti-evolutionary teachings. Liberal Christians, however, interpret parts of Scripture (the Christian Bible) more as stories, albeit with an important message or a greater truth, but not necessarily describing events that actually took place.



#### 2.5.4 Measuring Christian Worldviews

In an attempt to describe the diversity inherent in a Christian worldview, the properties of a Christian Worldview can be broken down into three broad categories. These are core Christian beliefs (Christian orthodoxy), interpretation of Scripture (biblical literalism), and the personal importance of religion to everyday life (religiosity). These three properties can be combined as shown in Figure 2.3.

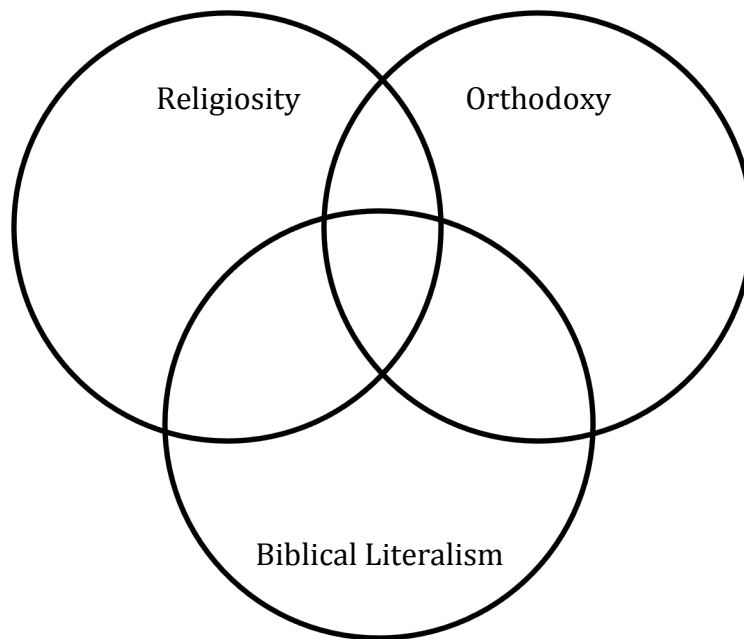


Figure 2.3 *Relationship between strands of a Christian worldview.*

Scriptural literalism refers to how literally an individual reads the Bible and is one measure of the type of Christian worldview to which an individual belongs. It describes their deep-rooted understanding about the nature of the Bible and therefore how they believe they are expected to interact with it, including their response to a range of socioscientific issues such as those involving cloning, IVF, genetic modification of plants and animals, and pre-embryonic genetic testing. Evensen et al. (2000) has shown that students identifying with a young earth creationist worldview are more likely to object to applications of biotechnology, and are linked to intrinsic objections to the technology. That aspect of a Christian worldview that describes core beliefs, such as those about God and his action in the world, can be measured through a Christian orthodoxy scale. This scale describes the extent that an individual agrees with core Christian religious beliefs. Religiosity is a measure of the

religious activity and religious dedication of the individual. This scale is used as a measure of the importance of religion in the individual's life and provides an approximation of the impact or importance that Christian belief has on their personal worldview. While it seems unlikely that a worldview that includes a strict biblical literalism would exist outside conservative Christian orthodoxy, the remaining combinations would reflect the diversity found within the Christian worldview, provided that these three properties are not taken as binary factors. Rather, an individual could hold to some but not all core beliefs (Christian orthodoxy), or take some, but not all, of the Bible as events that actually happened (biblical literalism), and the importance of their beliefs, referred to here as religiosity, may range from being of no, limited or mild importance to absolute importance.

The small number of studies that have researched a religious perspective of attitudes towards biotechnology have typically utilised a simplistic measure of Christian worldview. This distinction is important in light of the findings of Wolkomir, Futreal, Woodrum, and Hoban (1997), who have shown that there is a difference between adherence to conservative Christian doctrine, measures of religious behaviour such as church attendance, and biblical literalism. This suggests the need to differentiate between these three aspects of the religious worldview. A measure of Christian worldviews that utilises the three parameters of Christian orthodoxy, biblical literalism, and religiosity, responds to the concerns made by a number of researchers who have suggested the need for multiple measures of belief in research of this nature. This allows for distinctions to be made between the presence of specific ideologies or beliefs and of the importance that individuals impute to such beliefs (Eckberg & Blocker, 1996; Nielsen, Williams, & Randolph-Seng, 2009).

## 2.6 RELIGION AND ETHICAL ARGUMENTS ABOUT BIOTECHNOLOGY

Biotechnology comprises some techniques that challenge Christian worldviews and therefore raise questions regarding the morality of genetic engineering (Cole-Turner, 1997). This section reviews the role of religion in moral judgements and attitudes about biotechnology. It commences with a description of the key concerns of religious groups, as presented in the literature. Despite the publicity of these concerns, official statements from religious organisations are often supportive of the goals of biotechnology and, with some notable exceptions, do not provide theologically based arguments for the intrinsic wrongness of biotechnological

processes. Both the religious concerns and the perceived support for biotechnology are discussed and analysed. The section concludes with a review of studies that have examined religious belief and attitudes towards biotechnology and identifies some of the key findings and limitations of the current research in this field.

### **2.6.1 Religious Concerns about Biotechnology**

It has been shown that general moral attitudes (Scheepers & Slik, 1998) and attitudes about science and technology issues (Hayes & Tariq, 2000) can be predicted by general religious beliefs. More specifically, a number of studies have demonstrated a negative association between attitudes towards biotechnology and religious belief (John Evans, 2002; M. D. R. Evans, 2011; Evensen et al., 2000; Jordahl, 1993; Nielsen et al., 2009; Nisbet, 2005). Some of the religious concerns are expressed in the official statements of church groups, with the United Methodist Church (1991) highlighting their concern in a statement that reads in part:

Failure to accept limits by rejecting or ignoring accountability to God and interdependency with the whole of creation is the essence of sin. Therefore, the question is not can we perform all prodigious works of research and technology, but should we? (p. 2)

This statement reveals the basis of many religious concerns about biotechnology through the suggestion that the essence of sin is rejecting or ignoring accountability to God. The Christian worldview places God as an authoritative figure, and therefore any technology that undermines God's authority will be questioned by those who live within this worldview. The Christian worldview does, of course, offer a broad spectrum of ideas about God's nature, including the authority of God. However, just as the fundamentalist worldview gives more credence to the Bible as a literal and authoritative document, and in doing so rejects any science that undermines this authority, it logically follows that any technology that undermines their ultimate source of authority, God, will likewise be rejected. It is therefore scriptural literalism, the proxy measure of fundamentalism, which will theoretically be more associated with the rejection of biotechnology.

This fear about the rejection of God as authority provides the catalyst for five religious based concerns about biotechnology that are often addressed in the literature. These concerns consist of: the moral state of a human embryo, playing

God, slippery slope, God is Creator, and God's will. A more detailed discussion of each of these concerns is hereby addressed.

#### ***2.6.1.1 The Moral State of a Human Embryo***

The one issue that stands out above all the others with regard to religious concerns about biotechnology is the harm or destruction of a human embryo and for many religious groups the embryo is given the same moral status as a child. Amongst the world religions, Christianity is uniquely concerned about the embryo and often equates abortion with murder (Cole-Turner, 2006). Despite this, throughout the history of Christianity there has been a broad, and often conflicting, range of opinions regarding the moral status of the embryo. These views range from fully human, or the presence of a soul at conception, or possibly at a specific time frame after conception, to a more developmental approach of becoming human throughout the term of the pregnancy (Collins, 2006; Ford, 2002; Jones, 2004). The special status given to the embryo in the Christian tradition places significant constraints on much of the biotechnology involving humans. For many Christians, this includes cloning for biomedical research, as the embryo is seen as being fully human from the moment of fertilisation, therefore any act which involves the intentional death of an embryo, which by necessity includes any research on human embryos, is equated with the biblical command 'though shalt not kill' (Wolfson, 2003). This too is one of the contributing factors in the Catholic position against IVF. However, official disapproval of a technology by a Christian organisation does not necessarily reflect the attitude or behaviour of individual members. As an example, the Catholic church opposes the use of stem cell therapy, on the grounds that stem cells are derived from embryos, and yet M. D. R. Evans (2011) has shown that there is little difference between Catholic laity and Protestants when they were asked if they would use the technology.

#### ***2.6.1.2 Playing God***

The use of the term 'playing God' has been discussed at depth in the literature (Barab et al., 2010; Chadwick, 2009; Erde, 1989; Polkinghorne, 2000; Ryan, 1995; Verhey, 1995; Weasel & Jensen, 2005), but Verhey eloquently summarises the depth of meaning found within this term in his 1995 essay entitled "*Playing God*" and *Invoking a Perspective*".

Unfortunately, the phrase does not mean just one thing; it means different things to different people in different contexts. That is hardly surprising, I suppose, given the fact that neither "play" nor "God" are simple terms. Moreover, sometimes the phrase is used in ways that have nothing to do with either "play" or "God". (p. 348)

Verhey (1995) goes on to explore some of the different contexts within which the phrase is used, and suggests that it can have deep theological meaning. Other commentators disagree, suggesting that the phrase itself is meaningless, and at most is a pseudonym for 'not natural' (Erde, 1989; Wachbroit, 2003). It is, however, apparent that most authors who have discussed this phrase believe that it can and does have meaning at least for some individuals (Dragojlovic & Einsiedel, 2013; Gaskell & Bauer, 2001; Polkinghorne, 2000). Research by Dragojlovic and Einsiedel (2013) has indicated that for strong believers 'playing God' is a separate issue to just being unnatural. Polkinghorne (2000) emphasises the difference between 'unnatural' and 'playing God' by contrasting the different responses to the 'unnatural' but life-saving act of a heart transplant; he suggests that the term 'playing God' has more significance than just 'unnatural'. In the extreme, use of the phrase 'playing God', in both its theological and non-theological forms, is an indictment against the advances of modern technology, as Cole-Turner (2006) explains.

The phrase 'playing God' rightly calls attention to the human tendency toward hubris that readily accompanies success in technology. Succeeding in one thing, we think too quickly that we can succeed in all things, and that our success is unambiguously good. We overestimate our abilities and, most of all, our moral maturity, refusing to see our own egocentrism and blind spots. The theologian Paul Ramsey captures the rhetorical power of the phrase in his comment that 'Men ought not to play God before they learn to be men, and after they have learned to be men they will not play God'. (p. 942)

In qualifying this remark Cole-Turner (2006) emphasises that he believes it is not technology itself that is out of control, but that society lacks the means, and individuals lack the responsibility, to use these powers wisely. The theological significance of this phrase is enlightened further by Scruton (2007) in his essay, "The Trouble with Knowledge".

Religious people, who see their time on earth as a pilgrimage, will have no difficulty in understanding that some discoveries should not be pursued; didn't death enter the world through the lust for knowledge? There are techniques that we ought not to develop since in developing them we are playing at God, as Adam played at God in trying to distinguish good and evil for himself. (p. 84)

Here we see an objection to biotechnology on the grounds that it challenges God's divine wisdom, *omniscience*, and for some believers this will inevitably have unintended consequences. In addition, the phrase 'playing God' is also an objection against undermining the power of God, *omnipotence*, and therefore devalues God (Chadwick, 2009). It is no wonder then that some Christians object to biotechnology with the claim that scientists are 'playing God'.

#### **2.6.1.3 *Slippery Slope***

The idea that a particular technological advancement, while not perceived as being intrinsically wrong, may result in morally questionable actions in the future, is referred to as the slippery slope argument. Sandel (2004, p. 51) used this argument when he stated, "we live in a world where science moves faster than moral understanding". The slippery slope argument can be explained from the example of pre-implantation genetic screening (PGS), a technique currently used whereby a single cell is removed from a developing embryo without harming it so that genetic test can be done to determine the health of the future child. Three religious objections are typically made regarding this procedure. For those that object to IVF this technology would clearly be unacceptable, as would any reproductive technology that uses IVF. Many Christians do not object to IVF. However, they would object to the use of PGS on the grounds that any embryos that are identified as having a genetic disorder would then be destroyed. As has been pointed out by others, this is morally no different to the standard ultrasound test performed on nearly every unborn child in the developed world (Cole-Turner, 2006). In this case the slippery slope is a very steep one, a morally justifiable act, namely PGS, would almost certainly lead to what is a perceived as morally unjustifiable act, the destruction of an embryo. Still other Christians, those that do not view the human embryo as being equivalent to human life and therefore may not object to technologies such as stem cell therapies, may still object to PGS on the grounds that it will make it easier for a future technology which they consider to be morally wrong, typically genetic enhancement of embryos, to be carried out at some future time (Cole-Turner, 2006). At a deeper level, Song (2002) suggests that the slippery slope argument is a resignation to the inevitability, at some future time, of technology applications considered ethically abhorrent to many individuals and religious organisations.

#### **2.6.1.4 *God is Creator***

Within religious thought there is a concept that calls for respecting all of life because it was created by God and therefore must have value even if we do not recognise it. This is seen in a statement by the United Church of Christ (1990) regarding biotechnology, which reads in part:

God is creator of all and confers value upon all creatures. God sustains creatures through the intrinsic interdependence of all creation. Therefore we respect each creature as valuable to God beyond its apparent usefulness to us. (p. 43)

This respect is manifested in different ways, however some individuals see this as a moral argument to refrain from genetic manipulation of plants and animals. When the biotechnology is associated with humans, theologians often appeal to the Christian doctrine that humans are created in the image of God; this idea is used in a similar manner to the concept of dignity that is often used by secular ethicists (Cole-Turner, 2006).

#### **2.6.1.5 *God's Will***

One of the reasons that religious individuals object to technology such as PGS, genetic enhancement, and other reproductive technologies, is the belief in the concept that individuals should be happy with the situation that God has given them. For some this may be problematic because it gives those with the means an unfair advantage (Kass, 2003), but others hold to the view that everything in nature and God's creation has an intended purpose, therefore we should accept both the good and the bad times that come (Gaskell & Bauer, 2001; Wachbroit, 2003). Kass (2003), commenting on human enhancement, eloquently summarised this concern when he wrote:

When nature deals her cards, some receive only from the bottom of the deck. Conversely, it is often the most gifted and ambitious who most resent their limitations. Achilles was willing to destroy everything ... so little could he stomach that he was but a heel short of immortality (p. 14).

Furthermore, Christians proclaim that humans were created in the image of God, and therefore embryo research not only destroys a life, but meddles with God's plan for that life (Silver, 2009).

### **2.6.2 Support and Concerns of Biotechnology from Religious Organisations**

While there appears to be a trend in the literature linking religious belief to decreased

support for many of the recent and future biotechnological advances, a broad review by Cole-Turner (1997) of official publications from religious organisations concluded that few groups expressed inherent concerns with biotechnology. Instead, it appears that most organisations are actually largely supportive of the goals associated with biotechnology (Silver, 2009; P. Thompson, 2007). Cole-Turner (1997) summarised the main concerns of religious groups as being:

1. Justice in the distribution of the risks and benefits of biotechnology.
2. A perceived tendency towards materialistic reductionism or commodification of the intrinsic value of human life.
3. The use of prenatal genetic testing and its relationship to abortion.

In commenting on what he perceived as a strong support for biotechnology by the world churches, Cole-Turner (1997) noted that biotechnology offers opportunity for the expression of the fundamental attitudes of compassion, altruism and a commitment to healing, all of which are central characteristics of Christian thought and teaching. Rather than being critical of biotechnology, it was observed that these statements took the view that humans are superior to all species and can therefore alter them in any way that meets human needs. Likewise, P. Thompson (2007), who also found that official statements by churches were broadly supportive of biotechnology, concurred with this view and offered two statements from United Church of Christ (1990) as examples.

Genetic engineering gives us new ways to relieve suffering and increase food production,.... We support the application of genetic engineering to agriculture, forestry, mining and pollution control, provided there is adequate regulation and public participation in evaluating new uses. (p. 43)

As was observed by Cole-Turner (1997) and P. Thompson (2007), this support came with some qualifications in that when it is used, the technology will be used fairly and not for harm.

### **2.6.3 Discussion of Religious Concerns**

As has been shown, there is a range of opinion within Christian thought about the appropriateness of biotechnology. Those religious leaders and commentators who emphasise the benefits of biotechnology appear to be approaching the issue from a different paradigm to those who are more critical of biotechnology. Those who support biotechnology are associated with the idea that humans are ‘co-creators with God’ (Day, 2005; Lachmann, 2001; Ryan, 1995), while individuals and groups that



show more concern for biotechnology are linked to a theology that emphasises a 'perfect divine creation' and are more likely to see biotechnology as 'playing God' (Lachmann, 2001; van den Belt, 2009). It is useful to consider these two ideas as a spectrum of thought rather than binary theological positions, and in doing so it is possible to observe some trends that may account for the differences in attitudes towards biotechnology that exist within the Christian community. Fundamentalist Christians, those typically associated with young earth creationist views, were shown by Evensen et al. (2000) to be more likely to object to biotechnology, and those objections would more likely involve intrinsic objections against the technology rather than concerns about consequences. Fundamentalist Christians are also likely to hold a view of 'perfect divine creation' and as such have a less active role for humans in the creation process (van den Belt, 2009). They also believe in a God that intervenes more in everyday life (Froese & Bader, 2010). According to research by G. Smith (2005), fundamentalist Christians are the group most likely to look to their religious beliefs when making life and moral decisions. Conversely, Liberal Christians are more likely to see the task of humans as 'co-creators with God' and therefore perceive a more active role for humans in the creation process (Lachmann, 2001; van den Belt, 2009). In discussing this fundamentalist versus liberal distinction, Greeley (1993) and Eckberg and Blocker (1996) suggest that differences in attitude between the two groups may result, not from biblical interpretations, but because the issues have become politicised, with the Christian right reacting to the religious left. Finally, it should be noted that the ethical arguments of theologians may not be manifested in the average church member, and especially in students, whose level of theoretical understanding and interest may be low (Eckberg & Blocker, 1996).

#### **2.6.4 Christian Worldviews and Biotechnology Attitudes**

A careful review of the available literature has revealed only a limited amount of research investigating Christian worldviews and attitudes towards biotechnology. This section will present the findings of seven studies that have had as their primary purpose the investigation of this topic. All of these studies come from North America and most involve the general population, with the exception of two that involved college (undergraduate) students. The issues addressed in these studies have normally been confined to one or two biotechnological issues and these have included cloning (two studies), stem cell research (two studies), genetic modification

of plants and animals (one study), human genetic manipulation (one study) and faith in 'modern biotechnology' to solve world health and social issues (one study). These studies are mostly in agreement with each other, showing a decreasing acceptance of biotechnology with increased religious belief. A summary of these studies can be found in Table 2.2, which identifies the participants, sample size, country of origin, issues addressed and key findings of each study. Other studies that have incorporated measures of religious belief, but where it has not been the main focus of the research, have provided a mixed set of results regarding the relationship between attitude towards biotechnology and Christian belief.

Research about attitudes towards cloning has been conducted by John Evans (2002) using data from a survey conducted by the Pew Research Centre in March 2001. The results were presented by the author as a preliminary study to guide future research, and some methodological concerns with the research have been identified. The survey did not differentiate between therapeutic cloning and reproductive cloning, although the author assumes that responders were considering reproductive cloning as therapeutic cloning had received very little public attention. The survey utilised a limiting differentiation of religious groups, with Protestants being described as Evangelical or Liberal without separately identifying Fundamentalist. The research by John Evans (2002) showed that most people opposed cloning; however, Evangelical Christians who attended a religious service 'once or twice a month' or more were even more opposed to cloning than the general population. It also demonstrated that Evangelical Christians were more likely to view cloning as a religious issue. This is unsurprising, as it had been shown previously that Evangelical Christians tend to view religion as an important factor in making any decisions about public affairs (Regnerus & Smith, 1998).

A qualitative study on human cloning by Weasel and Jensen (2005) incorporated a web based data collection methodology to explore the views about cloning from Fundamentalist church pastors and qualified scientists. The researchers found that both groups rejected reproductive cloning, and the scientists were considerably more supportive than the pastors of therapeutic cloning. When it came to articulating the reasons for their views, the pastors were much better than the scientists at providing reasons and values for their opinions.

Table 2.2 *Studies Examining Christian Worldviews and Biotechnology Showing Participants, Sample Size, Country of Origin, Issues Addressed, and Key Findings*

Study	Participants	N	Country	Issues addressed	Key findings
John Evans (2002)	General Public	1892	USA	Human Cloning	<ul style="list-style-type: none"> <li>• Regularly attending, evangelical Christians are more opposed to cloning than the general public.</li> <li>• Evangelical Christians are the only group that viewed cloning as a religious issue.</li> </ul>
Nisbet (2005)	General Public	2122	USA	Stem Cell Research	<ul style="list-style-type: none"> <li>• Fundamental Christians are more opposed to stem cell research.</li> </ul>
Nielsen et al. (2009)	Undergraduate psychology students	151	USA	Stem Cell Research	<ul style="list-style-type: none"> <li>• Biblical literalism is a good predictor of moral opposition to stem cell research.</li> </ul>
Evensen et al. (2000)	General Public	1226	USA	Genetic modification of plants and animals	<ul style="list-style-type: none"> <li>• Fundamental Christians have a greater intrinsic moral objection to biotechnology.</li> </ul>
Jordahl (1993)	Undergraduate College Students	86	Canada	Human Genetic manipulation	<ul style="list-style-type: none"> <li>• Students attending a Bible college campus strongly oppose gene manipulation.</li> <li>• Students attending a Bible college campus were more opposed to gene manipulation than US college students in general.</li> </ul>
Scheitle (2005)	General Public	783	USA	Using biotechnology to solve world health and social issues	<ul style="list-style-type: none"> <li>• Those individuals that believe in a “personal God that answers prayers” are more optimistic about biotechnology.</li> </ul>
Weasel and Jensen (2005)	Fundamentalist Pastors and Research Scientists	61	USA	Cloning	<ul style="list-style-type: none"> <li>• Pastors and Scientists both oppose reproductive cloning.</li> <li>• Scientists are more supportive of therapeutic cloning than Pastors.</li> <li>• Pastors are more likely to articulate reasons for their views than scientists.</li> </ul>

In a statistically robust study of attitudes towards stem cells, Nisbet (2005) showed that a stronger religious belief, as well as church attendance, was negatively associated with the acceptance of stem cell research, although religious belief was the more dominant factor of the two. In addition, the researcher was able to show that the abortion debate contributed to the polarising views towards stem cell research found in religious individuals.

While attitudes amongst moderate-believers and non-believers were moderated with an increase in awareness or knowledge of stem cell research, for those individuals with a strong religious belief, opposition towards this research was unaffected by the individual's knowledge of the topic. Nisbet's study used two criteria to measure the strength of religious belief, biblical literalism and religious salience (importance of religious belief). Therefore, in this study strong religious belief corresponds to a highly literal interpretation of the Bible, and these individuals could readily be described as Fundamental Christians.

Building upon Nisbet's (2005) study, Nielsen et al. (2009) utilised a broader array of religious measures as well as a more nuanced measure of concerns about stem cell research; this gave the researchers the ability to differentiate moral concerns of stem cell research and other concerns such as institutional ethical concerns, and funding concerns. The results confirm those of Nisbet (2005) by showing that an increase in religious belief is associated with an increased concern over stem cell research. More specifically, it was shown that biblical literalism uniquely contributed to moral objections to stem cell research, explaining 24% of the variance in the moral objection to the technology.

Research exploring attitudes about biotechnology involving plants and animals Evensen et al. (2000), using a worldview conceptual framework, showed that Fundamentalist Christians were predisposed to find biotechnology morally wrong. The authors also provided evidence suggesting that Fundamentalist Christians were more likely to view genetic engineering as intrinsically wrong.

Jordahl (1993) utilised a survey instrument to measure students' reactions to genetic engineering as associated with correcting genetic defects and human enhancement. Results from the survey had previously been reported for a range of public colleges across the United States of America, and these were compared to the results using

the same survey from students attending an evangelical Bible college (tertiary education). The author was able to show that these students strongly opposed gene manipulation and were more opposed than US college students in general. They also displayed less indecision about the issues than their peers at other universities. While this study supports the previous studies in suggesting that Evangelical and/or Fundamentalist Christians are more opposed to biotechnology, it is limited methodologically because of the small sample and by its failure to contain any direct measure of religious belief.

In contrast to all of the other research presented here, a study by (Scheitle, 2005) found that in the United States there was no difference in the optimism about biotechnology amongst a survey of the general population on religious grounds, except for those individuals who believed in a ‘personal God that answers prayers’; this group demonstrated more optimism than the general population. The author of this study surmised that religious belief provided a safety net for believers in that an all-powerful God would help guide the technology and protect against any negative consequences. While presenting the unexpected results of his study, the author identified a number of significant limitations. Because the study used pre-existing data from a 1997-1998 US biotechnology study, the limited questions addressing religious belief did not allow for differences between fundamental and liberal theological beliefs. For the same reason, the term ‘biotechnology’ was ill-defined and did not address the morality of these issues, focusing rather on the possibilities of biotechnology as a whole. While this research reflects some of the optimism and support for biotechnology associated with religious organisations, and that has been described in Section 2.6.2, it is clear from other studies (John Evans, 2002; Jordahl, 1993) that the issue requires further analysis.

A number of studies have included measures of religious belief as part of a control measure in a broader investigation of attitudes towards biotechnology. The results of these studies, with regard to the effects of religious belief, are mixed. Some studies have shown no statistically significant relationship between religious belief and attitudes towards biotechnology (Costa-Font & Mossialos, 2006; Klop & Severiens, 2007; Macer et al., 1995), while others indicated a negative association between these two variables (M. D. R. Evans, 2011; Hayes & Tariq, 2000; Simon, 2010). These studies have typically used an over-simplistic measure of religious belief that,

while justifiably appropriate for a control measure, should not be used to explore the role of religious belief in attitudes towards biotechnology. Those studies described here that have been specifically designed to examine some aspect of the Christian religious worldview have typically found that an increase in religious belief was associated with negative attitudes towards a range of biotechnological issues.

## 2.7 SUMMARY OF CHAPTER

Chapter 2 consisted of an exploration of the literature based around the three research questions.

1. How does religious belief act as a predictor of attitudes towards biotechnology?
2. Does the acceptance of a Christian belief affect students' patterns of informal reasoning?
3. How are students' religious beliefs incorporated into their informal reasoning about biotechnology?

Section 1 introduced the five areas of research that were addressed in this chapter: socioscientific issues, attitudes towards biotechnology, informal reasoning, moral judgement and Christian worldviews, and the role of Christian religious beliefs in attitudes about biotechnology.

Section 2 of has provided an overview of the literature on the socioscientific issues movement, including the historical development of this field of inquiry and the educational benefits that this approach to science education may have for students. Two recent areas of research into the socioscientific issues movement, classroom discourse and cultural issues, position this present study firmly within the socioscientific issues movement, and a limitation in the literature on socioscientific issues movement is identified by showing that the literature does not adequately address the role of Christian religious beliefs in students' reasoning and attitude towards biotechnology.

Section 3 then explored attitudes towards biotechnology. It began with a definition of biotechnology, in accordance with how that term is manifested in the present study, and continued by presenting the multicomponent model of behaviour, including the affective, cognitive and behavioural components, as a theoretical framework for the development of students' attitudes towards biotechnology. Gender differences in

attitudes towards biotechnology, as reported in the literature, were discussed. The conclusion was reached that females were less supportive of biotechnology, and the resulting implications for the current study were addressed. The difficulties faced by researchers in measuring attitudes towards biotechnology were identified and these limitations were used to suggest that the qualities of an ideal questionnaire to measure biotechnology attitudes would: include cognitive, affective and behavioural components of attitude; provide opportunity for open-ended responses; include a range of biotechnology applications; have the ability to make comparisons with other studies; and be constructed and validated using standard statistical procedures.

Section 4 addressed informal reasoning. It started with a definition of informal reasoning and an examination of the different approaches to informal reasoning that have been used by various researchers. The discussion then elaborated upon one of these methods, patterns of informal reasoning, and provided descriptions of the three modes, rational, emotive, and intuitive reasoning, which make up this method of categorising students' informal reasoning. The section continued with an in-depth look at five studies, all of which identified rational, emotive and intuitive modes of reasoning in students' thinking about biotechnology issues. Research was presented that showed how different socioscientific issues may alter students' patterns of informal reasoning, and how cultural differences, including religious beliefs, may have an impact on students' use of the three modes of reasoning.

Section 5 reviewed moral judgement and Christian worldviews. A definition of moral judgement revealed the importance of worldview in ethical decision-making and subsequently the concept of worldview was further explored. From this exploration it was concluded that worldview: is culturally organised; influences the way that individuals think about an issue; defines what an individual describes as self; and is constructed through physical and social interactions. The significance of these conclusions to the considerations of the three research questions addressed in this study was discussed. After carefully considering what a Christian worldview looks like, including the diversity that exists amongst Christian believers, a framework for measuring a student's religious belief that is consistent with a worldview approach was presented. Upon examination of the literature, it was suggested that to find a robust measure of an individual's Christian worldview the

three categories of Christian orthodoxy, biblical literalism and religiosity must be incorporated into the questionnaire.

Section 6 explored the role of Christian religious belief in moral judgements about biotechnology. It started by identifying five concerns that have been raised by Christian groups and theologians. These commentators on biotechnological advances have suggested that the ‘moral state of a human embryo’, ‘playing God’, ‘slippery slope’, ‘God is Creator’, and ‘God’s will’ may provide the grounds for discontinuing or not pursuing certain biotechnological techniques. This criticism of biotechnology is contrasted with the widespread support from many official Church organisations towards the goals of biotechnology. Finally, a review of the research linked fundamentalist Christians to non-supportive attitudes towards a range of biotechnological processes.

This chapter is followed by Chapter 3, which describes how the research project was designed and then implemented to address the three research questions under investigation in this study. It outlines the research approach and the research design used in the study, including the procedures used in the collection and analysis of the data.



## **Chapter 3**

### **METHODOLOGY**

#### **3.1 INTRODUCTION**

Chapter 2 presented a literature review that grounded this study within the research field of the socioscientific issues movement. Attitudes towards biotechnology were discussed, including the implications for the construction of a questionnaire to measure those attitudes and a review of patterns of informal reasoning suggested a method for categorising different modes of students' thinking about biotechnology. An exploration of moral judgement and Christian worldviews provided a framework for measuring Christian worldviews, and a look at the role of Christian religious beliefs in judgements about biotechnology offered an insight into some of the concerns that students may have regarding biotechnology.

As indicated in Chapter 1, the purpose of this study was to address the following research questions:

1. How does religious belief act as a predictor of attitudes towards biotechnology?
2. Does the acceptance of a Christian belief affect students' patterns of informal reasoning?
3. How are students' religious beliefs incorporated into their informal reasoning about biotechnology?

In this chapter, the methodology for comparing students' religious belief with their attitudes toward biotechnology and informal reasoning patterns will be explained. A justification will be made for the use of both qualitative and quantitative research methods and how triangulation, and the use of mixed methods have been used to ensure the rigour of the research and its conclusions (Creswell, Clark, & Vicki, 2007). Details will be provided outlining the sample, methods utilised, the instruments used, as well as the procedures followed for gathering and analysing the data.

#### **3.2 RESEARCH APPROACH**

This research project aimed to explore the role of Christian religious beliefs on students' attitudes towards biotechnology. There are many factors that may influence an individual's attitude and also many nuances to the problem being researched. Working within a worldview of methodological pragmatism, this mixed methods study incorporates both qualitative and quantitative methods to explore the questions

being addressed. As a research paradigm, pragmatism draws upon a diverse range of research approaches, placing value in both objective and subjective knowledge, and maintaining the research question as primary importance, even over the method or the philosophical paradigm that underlies the method (Cherryholmes, 1992; Tashakkori & Teddlie, 2003). Qualitative research is characterised by the collection of open-ended information (Creswell et al., 2007), including interviews and extended response questions that allow participants to provide their own perspective on the questions being asked. Quantitative research involves the collection of closed-ended information (Creswell et al., 2007) such as is typically obtained through the use of questionnaires. By using a mixed methods approach to this research, a disciplined and structured inquiry of the problem that utilises the strengths of both methods can be undertaken. The overarching theme of mixed methods research is that it provides an epistemological approach that attempts to consider multiple perspectives on an issue, including the viewpoints of both qualitative and quantitative research (Johnson, Onwuegbuzie, & Turner, 2007). After reviewing definitions of mixed methods by leaders in this field of research, Johnson et al. (2007) suggests the following definition which will be used for the purposes of this study:

Mixed methods research is the type of research in which a researcher or team of researchers combines elements of qualitative and quantitative research approaches (e.g. use of qualitative and quantitative viewpoints, data collection, analysis, inference techniques) for the broad purposes of breadth and depth of understanding and corroboration. (p. 123)

By utilising the above definition, the advantages of generalisability offered with quantitative data can be supported by the qualitative data, providing the necessary individual perspective and thereby providing context for the study (Creswell, 2008). This process of triangulation, which incorporates the use of both quantitative and qualitative methodologies, is strongly supported in the literature, with Tobin and Fraser (1998, p. 639) concluding that “we advocate the use of both in an effort to obtain credible and authentic outcomes”. Many researchers (Creswell et al., 2007; Denzin, 1978; Jick, 1979) have advocated the use of more than two methods in order to obtain a more holistic view of the phenomenon being studied. The use of mixed methods is not without precedent in the study of secondary school students’ attitudes towards science (Buck, Cook, Quigley, Eastwood, & Lucas, 2009), and public attitudes towards biotechnology (Guehlstorf, 2008; Klop, 2008; Shepherd et al.,

2007), all of which have combined qualitative and quantitative data in a mixed method design.

The methodological triangulation (see Figure 3.1) involved the use of the Biotechnology Attitudes and Religious Belief Questionnaire (BARBQ) to collect both qualitative and quantitative data, while the student focus groups provided an additional method of collecting qualitative data.

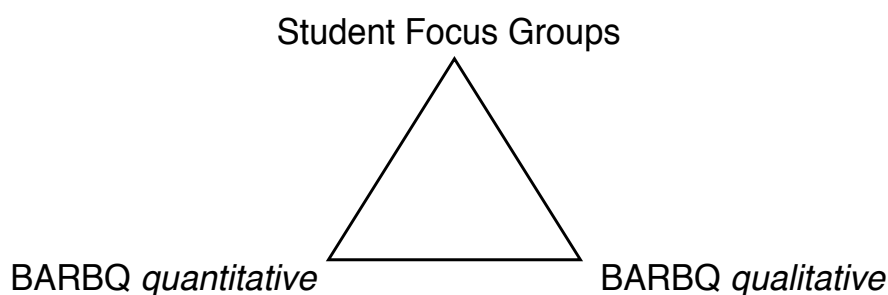


Figure 3.1 *Methodological triangulation used in the study.*

The quantitative component of the study utilised an explanatory research design which, as Creswell (2008, p. 358) describes, is appropriate when “the researcher is interested in the extent to which two variables (or more) co-vary”. Questionnaires were chosen as the primary instrument for gathering data. This allowed for data to be collected from a larger number of individuals, thereby allowing the data to be more representative of the students within the school system being investigated along with allowing for more reliable statistical analysis (Creswell, 2008). The use of four focus groups as a qualitative source of data allowed for the triangulation of the primary data as well as providing additional insights into the ethical decision-making process of the students. The semi-structured nature of the interview provided the researcher with an opportunity to establish rapport with the participants and also gave the interviewer the freedom to explore interesting areas that arise from the discussion (Fontana & Frey James, 2000). Table 3.1 outlines the research strategy used for each question. An overview of the methodological approach taken in this study is shown in Figure 3.2. Adapted from Creswell et al. (2007, p. 46), this figure outlines the procedures in the study and shows how the qualitative and quantitative data will be combined to provide overall results and interpretation.

Table 3.1 *Methodology Used for Each Research Question*

Research questions	Method	Data Collection Strategy	Instrument/s Used	N	Data Analysis strategy
1. How does religious belief act as a predictor of attitudes towards biotechnology?	Survey	Closed questionnaire	BARBQ <i>quant</i>	177	Statistical correlation Regression analysis Comparison of means
2. Does the acceptance of a Christian belief affect students' patterns of informal reasoning?	Survey	Open questionnaire	BARBQ <i>qual</i>	138	Frequency tables
		Closed questionnaire	BARBQ <i>quant</i>	177	Division of sample into high and low levels of Christian religious belief
3. How are students' religious beliefs incorporated into their informal reasoning about biotechnology?	Survey	Open questionnaire	BARBQ <i>qual</i>	138	Identification of common ethical arguments Frequency tables
		Closed questionnaire	BARBQ <i>quant</i>	177	Difference of means
	Focus group	Semi-structured interview	Interview protocol	23	Identification of common ethical arguments

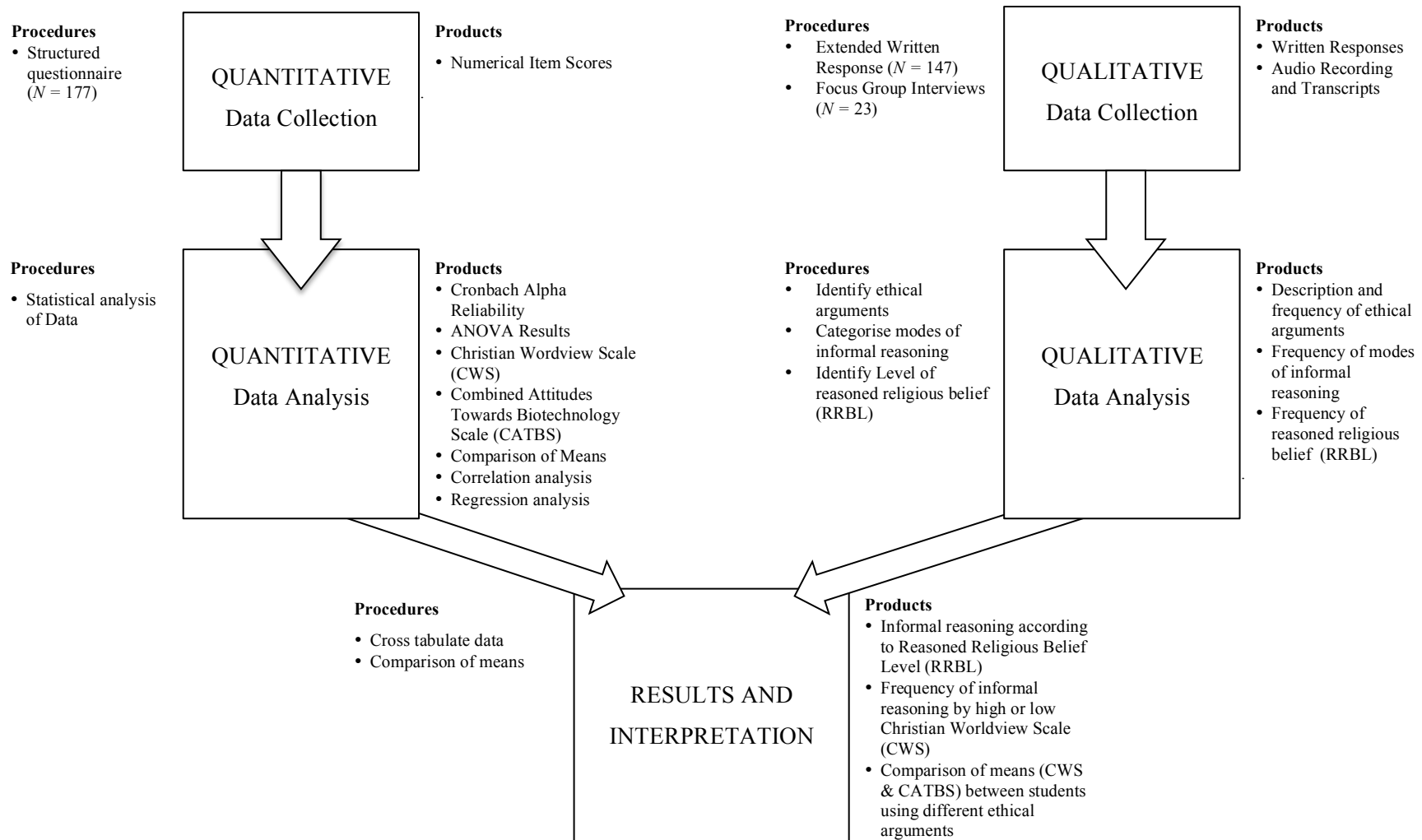


Figure 3.2 *Overview of the methodological approach to the study.*

### 3.3 RESEARCH DESIGN

#### 3.3.1 Sample

Senior secondary students (Years 11 and 12) from three faith-based schools in Victoria, Australia, were involved in this study. As a faith-based school system, a religious body or denomination financially supports these three schools, which in this case is the Seventh-day Adventist Church. Participants for this study were selected using a convenience sampling strategy (Creswell, 2008). The schools that were selected for this study were available to the researcher, in that he was employed by the school system and was familiar with the three schools. As a single Christian denomination group ran the schools, it meant that the three schools had similar educational and philosophical ideologies. However, a range of religious faiths, as well as nationalities and socioeconomic groups was represented in the schools. The Index of Community Socio-Educational Advantage (ICSEA), calculated by the Australian Curriculum, Assessment and Reporting Authority (ACARA), provides a numerical scale representing the magnitude of the educational advantage resulting from key factors that are known to influence a student's educational outcome (ACARA, 2013). The ICSEA scores indicate that all three schools are in the mid-range of the socio-educational advantage spectrum. A total of 181 students who were undergoing studies to complete their Victorian Certificate of education (VCE) participated in the study, representing a participation rate of 84.6%. Table 3.2 outlines the participation from each school, showing the number of senior secondary students attending the school as well as the ICSEA scores for each school community.

Table 3.2 *Participation of Students by School and Year Level*

School	School ICSEA value	Number of senior students attending	Number of students participating <sup>a</sup>	% Participation
School 1	1042	127	107	84.2
School 2	1047	65	57	87.7
School 3	1054	22	17	77.2
Total		214	181	84.6

Note. ICSEA = Index of Community Socio-Educational Advantage, obtained from myschools website, myschool.edu.au, accessed June 2011.

<sup>a</sup>Four questionnaires were subsequently removed from the data set.

### 3.3.2 Development of Student Questionnaire

After a review of the literature, a single questionnaire that measured those variables under consideration (biotechnology, Christian worldview and informal reasoning), could not be found. Therefore, a questionnaire was developed by combining and modifying five instruments previously documented and validated in earlier studies. Each scale was further validated in the present study. The resulting questionnaire was called Biotechnology Attitudes and Religious Belief Questionnaire (BARBQ). The questionnaire was divided into two methodological parts with the quantitative parts of the BARBQ (BARBQ*quant*) comprised of three sections: Demographic Information, Attitudes Towards Biotechnology and Christian Worldview. The second part of the questionnaire formed the qualitative part of the BARBQ (BARBQ*qual*) and consisted of one section containing open-ended responses to biotechnology dilemmas. Some of the sections were further divided into strands and scales that describe the specific content being measured and will be discussed in more detail later in this chapter. Table 3.3 outlines each part, section, strand and scale of the questionnaire, along with the research questions that are addressed by each section and the number of items used to measure it. Where appropriate, the reported reliability from the original or earlier studies is shown, along with the original source of the questions.

Table 3.4 provides an example of the questions asked in the BARBQ for each strand or scale, along with the response options provided for that question. A full copy of the instrument is presented in Appendix A.

#### 3.3.2.1 *Structure of the BARBQ: Demographic Information*

The demographic information collected from the students was school, age, year level (Year 11 or Year 12), gender and any science- and/or religion-based subjects they were currently undertaking. This section was addressed in the BARBQ*quant* part of the BARBQ. A summary of the structure of this section of the BARBQ, including the number of items, reported reliability and the source of the questions are provided in Table 3.3. Sample questions and the response structure are provided in Table 3.4.

Table 3.3 *Overview of BARBQ*

Sections of the BARBQ	Research Questions addressed	Strand	Scales	Number of items	Reported reliability <sup>a</sup>	Source
<b>BARBQquant</b>						
1. Demographic Information				4		
2. Attitudes Towards Biotechnology	1	Cognitive	Biology and Genetics	9	$\alpha = 0.63$	(Klop, 2008)
			Biotechnology	16	$\alpha = 0.71$	
			Beliefs About Biotechnology	5	$\alpha = 0.70$	
		Affective	Emotions	13	$\alpha = 0.78$	(Klop, 2008)
			Inevitability	9	$\alpha = 0.76$	
			Concerns <sup>b</sup>	8	$\alpha = 0.79$	
		Behavioural	Own Intentions	5	$\alpha = 0.78$	(Klop, 2008)
			Medical Intentions	4	$\alpha = 0.74$	
3. Christian Worldview	1, 2, 3	Biblical Literalism		15	sb = 0.95	(Jennings, 1972)
		Christian Orthodoxy		6	$\alpha = 0.94$	(Hunsberger, 1989)
		Religiosity	Behavioural <sup>b</sup>	2	U	(Rohrbaugh & Jessor, 1975)
			Religious Salience <sup>b</sup>	2	U	(P. Hill & Hood, 1999)
<b>BARBQqual</b>						
4. Ethical Dilemmas	2, 3	GM Crops		1	NA	(Sadler & Zeidler, 2005a)
		PGS		1	NA	(Sadler & Zeidler, 2005a)
		Reproductive Cloning		1	NA	(Sadler & Zeidler, 2005a)
		Therapeutic Cloning		1	NA	(Sadler & Zeidler, 2005a)

Note. U = Unavailable; NA = Not applicable; sb = spearman-brown r; PGS = pre-implantation genetic screening.

<sup>a</sup> $\alpha$  = Cronbach's alpha, <sup>b</sup>Scale has been modified in the BARBQ from the original instrument.



Table 3.4 *Examples of Questions Found in the BARBQ*

Section/strand/scale of BARBQ	Sample Question	Response
<b>1. Demographic Information</b>		
<u>Age</u>	What is your current age?	16, 17, 18
<b>2. Attitudes towards Biotechnology</b>		
<u>Cognitive</u>		
<i>Biology and Genetics</i>	A human has 23 pairs of chromosomes in a regular cell nucleus.	True or False
<i>Biotechnology</i>	If you eat genetically modified fruit your genes may also be genetically modified.	True or False
<i>Beliefs About Biotechnology</i>	<i>Indicate how strongly you agree or disagree with the following statement:</i> Biotechnology makes our lives healthier, easier and more comfortable.	1-Strongly agree, 2-Agree, 3-Not Sure, 4-Disagree, 5-Strongly disagree
<u>Affective</u>		
<i>Emotions</i>	<i>Indicate how strongly you agree or disagree with the following statement:</i> Genetic modification of animals is wrong.	1-Strongly agree, 2-Agree, 3-Not Sure, 4-Disagree, 5-Strongly disagree
<i>Inevitability</i>	<i>Indicate how strongly you agree or disagree with the following statement:</i> Biotechnology is essential for human survival.	1-Strongly agree, 2-Agree, 3-Not Sure, 4-Disagree, 5-Strongly disagree
<i>Concerns</i>	How concerned are you about the genetic modification of plants?	1-Very Concerned, 2-Moderately Concerned, 3- Unsure, 4-Slightly concerned, 5-Unconcerned
<u>Behavioural</u>		
<i>GM Food Intentions</i>	<i>Indicate how strongly you agree or disagree with the following statement;</i> I would buy genetically modified food if it were cheaper than ordinary food.	1-Strongly agree, 2-Agree, 3-Not Sure, 4-Disagree, 5-Strongly disagree
<i>Medical Intentions</i>	<i>Would you be willing to:</i> Take a genetic test during your or your partner's pregnancy?	1-Definitely, 2-Probably, 3-Maybe, 4-Probably not, 5- Definitely not

(continued)

Table 3.4 *Examples of Questions Found in the BARBQ (continued)*

Section/strand/scale of BARBQ	Sample Question	Response
<b>3. Christian Worldview</b>		
<u>Christian Orthodoxy</u>	Through the life, death and resurrection of Jesus, God provided a way for forgiveness of man's sins.	1-Strongly agree, 2-Agree, 3-Not Sure, 4-Disagree, 5-Strongly disagree
<u>Biblical Literalism</u>	The miracles reported in the Bible actually occurred.	1-Strongly agree, 2-Agree, 3-Not Sure, 4-Disagree, 5-Strongly disagree
<u>Religiosity</u>		
<i>Behavioural</i>	When you have problems or difficulties in your school, family, or personal life, how often do you seek spiritual comfort?	1-Always, 2-Often, 3- Sometimes, 4-Rarely, 5-Never
<i>Importance</i>	In general, religious beliefs are very important in my day-to-day life.	1-Strongly agree, 2-Agree, 3-Not Sure, 4-Disagree, 5-Strongly disagree
<b>4. Biotechnology ethical dilemmas</b>		
Pre-implantation Genetic Screening	<p>Using in vitro fertilization (IVF) and genetic screening techniques it is possible to screen embryos before they are implanted. Using this technique it is possible to select the gender of a child or even make sure that it does not have certain diseases. In the future it may even be possible to select for other traits such as eye colour or intelligence.</p> <p>To what extent do you agree or disagree with the use of genetic screening?</p> <p>Outline as many reasons for your selection that you can.</p>	<p>Disagree           Agree</p> <p>25 lines for an extended response</p>

As described in Chapter 2, the students' knowledge of science may contribute to their attitudes towards, and reasoning about socioscientific issues. While specific biology and biotechnology knowledge was measured in Section 2 of the questionnaire, students were asked to indicate the science subjects they were currently studying. The Victorian Certificate of Education (VCE) science subjects offered by the three schools during the data collection phase in 2010 were VCE Biology, VCE Physics, VCE Chemistry and VCE Psychology. Details regarding the structure and content of each of these subjects can be located at the Victorian Curriculum and Assessment Authority's website, [vcaa.vic.edu.au](http://vcaa.vic.edu.au). A religion-focused subject, VCE Religion and Society, was compulsory for all students within the school system. The Religion and Society course, offered in all three schools, specifically explores contemporary ethical issues within the context of religious faith, as the following quotes from the VCE religion and Society Study Design demonstrate (Learner, 2010).

Students analyse how the ideas, values and ethical principles underpinning ethical perspectives are expressed through the formal aspects of religion ... [and] ... On completion of this unit the student should be able to analyse and evaluate two or more debates on contemporary ethical issues in pluralist society.” (pp.18, 19)

While the study design does not specifically refer to biotechnology issues, a discussion with the teachers of VCE Religion and Society at all three schools confirmed that they included biotechnology issues when teaching this part of the course. This unit of the study design is completed towards the end of Year 11 so only the Year 12 students in 2010 would have covered this content.

### ***3.3.2.2 Structure of the BARBQ: Attitudes Towards Biotechnology***

The items in this section measured students' attitudes towards biotechnology and incorporated cognitive, affective and behavioural measures of attitudes, as discussed in the literature review, so that a more accurate measure of students' attitudes could be obtained. After an extensive literature search, it was felt that the instrument used in Klop's (2008) study of Dutch secondary students best suited the structural requirements of the current study. This study measured sixteen-year-old students' attitudes to modern biotechnology and included 574 participants. The instrument used by Klop fulfils the requirements outlined in the literature review (Section 2.3.4.2), as it uses a range of biotechnology issues, including areas of modern

biotechnology, and is a statistically robust instrument. In a further fulfilment of the requirements outlined in the literature review, the instrument was developed using a framework that incorporated the cognitive, affective and behavioural components of attitude. The original instrument was written in Dutch and was translated into English using an online translation program and reviewed by a Dutch-speaking colleague. Some questions were modified for Australian students while attempting to maintain the integrity of each question. For example, 'Human cloning is prohibited in the Netherlands' was changed to 'It is currently prohibited in Australia to clone human embryos'. This section of the instrument was comprised of five strands and a total of 69 questions. The reliability of the original scale has been previously provided in Table 3.3 along with a summary of the structure of this section of the BARBQ, including the number of items, and the source of the questions. Sample questions and the response structure are provided in Table 3.4.

The Cognitive strand of this section measured students' knowledge and understanding about biotechnology that comes from their beliefs, thoughts and any previous knowledge they may have about biotechnology. To reflect the scope of the cognitive strand of attitudes towards biotechnology, the questionnaire was further broken down into three scales. The first scale, students' knowledge and understanding of biology and genetics, was measured using nine true or false questions. The second scale measured students' knowledge and understanding of biotechnology with 16 true or false questions. Five questions measured students' beliefs about biotechnology using a five point Likert response from strongly agree to strongly disagree.

The Affective strand measured students' feelings about biotechnology, such as fears and worries about the technology, and incorporated three scales to achieve this, the students' basic emotions towards biotechnology, their feelings regarding the inevitability of the technology and their level of concern about the technology. Thirteen questions measured the first scale and nine measured the second, both utilising five point Likert items ranging from strongly agree to strongly disagree. Students' level of concern about a variety of biotechnologies was measured with eight questions using a five-point Likert response ranging from very concerned to unconcerned. Klop's (2008) original instrument asked students about their concerns regarding in vitro fertilisation, genetic research, genetic modification and cloning.

These four issues were modified and expanded to eight concerns so that genetic modification and cloning of bacteria, plants, animals and humans could be differentiated.

The Behavioural strand of the Attitudes Towards Biotechnology section measured students' behavioural intentions rather than actual behaviours, given that it is unlikely that many of the students would be in a situation where they would be required to demonstrate such behaviours. The Behavioural strand consisted of two scales. Five questions measured students' behaviour towards genetically modified food and were measured with the same five-point Likert responses used in the preceding sections. Four questions measured students' behaviour towards medical applications of biotechnologies and asked students if they would be willing to use the technology described. Students responded to five-point Likert items, ranging from definitely to definitely not.

#### ***3.3.2.3 Structure of the BARBQ: Christian Worldview***

The third section of the questionnaire measured students' Christian worldview and consisted of three strands. Religiosity measured students' personal commitment to their religious beliefs and practices. Christian Orthodoxy measured the extent to which students accepted the core beliefs of the Christian faith. Biblical Literalism provided a proxy measure of fundamentalism by determining how literally students interpret the Bible. A total of 25 items, all of which utilised five-point Likert response items, was used to measure the students' Christian worldview. A summary of the structure of this section of the BARBQ, including the number of items, reported reliability and the source of the questions is provided in Table 3.3. Sample questions and the response structure are provided in Table 3.4.

The first strand in this section measured religiosity and consisted of two scales containing two items each. The first scale related to the students' behaviour and asked students to respond to the frequency that they attended religious services and their tendency to seek spiritual comfort when facing difficulties. These two questions were taken from a larger instrument developed by Rohrbaugh and Jessor (1975). Because all participating schools ran a compulsory religious-focused chapel program, students were instructed to exclude school-based chapel services when considering their response. The second scale related to religious salience, a term used to describe

the importance that students placed in their religious beliefs, and is frequently used as a measure of religiosity (Evensen et al., 2000; Schultz, Zelezny, & Dalrymple, 2000). Two questions were used to measure this scale, both developed by the researcher using examples presented by P. Hill and Hood (1999).

Christian Orthodoxy was measured in the second strand and consisted of six items, taken virtually unchanged from Hunsberger's (1989) Short Christian Orthodoxy (SCO) scale. In its original form this scale had a Cronbach's alpha of 0.94. The wording of questions 2 and 5 of the original scale was modified to better suit the secondary school students' reading level and knowledge. The second question in the original scale was written as, "The Bible may be an important book of moral teachings, but it was no more inspired by God than were many other such books in human history". This was changed to read, "The Bible is an important book of moral teachings, but it was not inspired by God any more than other historical books". The original wording of the fifth question in the original SCO scale read, "Despite what many people believe, there is no such thing as a God who is aware of our actions"; this was simplified to, "There is no such thing as a God who is aware of man's actions". Hunsberger (1989) used a six-point Likert scale in his original SCO scale; the BARBQ used a five-point Likert scale throughout this section of the questionnaire to obtain consistency and to minimise confusion among the participants.

Biblical literalism, the third strand used to measure Christian worldview, was measured with 15 items and utilised the Scriptural Literalism Scale (SLS) developed by Hogge (1967) and reviewed by Jennings (1972), who recorded a Spearman-Brown  $r$  coefficient of 0.95. The original instrument for the SLS contained sixteen items; however, item seven of the original instrument was very similar to the second item of the SCO scale and this was used instead of question seven in an attempt to shorten the length of the final instrument. To improve the readability for secondary students, a modified form of this scale was used which referred to the 'Bible' instead of using the term 'Scripture', as the original instrument did.

#### ***3.3.2.4 Structure of the BARBQ: Biotechnology Dilemmas***

In the final section of the questionnaire, four ethical dilemmas were presented to the students. The topics presented in this section were about genetically modified food,

pre-implantation genetic screening (PGS), reproductive cloning, and therapeutic cloning. Students were asked to indicate on a six-point scale the extent to which they agreed with the use of the technology. The use of a six-point scale in this section of the BARBQ was to force students to make a decision either way about the technology while still providing an opportunity for them to express their changing level of agreement across a range of technologies, from those considered mainstream to those considered highly controversial. Students were then instructed to outline as many reasons as possible for their decision to either agree or disagree with the use of the technology described. A summary of the structure of this section of the BARBQ, including the number of items, and the source of the questions is provided in Table 3.3. Sample questions and the response structure are provided in Table 3.4 with a full copy of the questionnaire located in Appendix A.

### **3.3.3 Development of the Interview format and protocol**

Whilst the emphasis in this research has been on the analysis of questionnaire data, for triangulation purposes focus group interviews were also conducted. The interviews provided the opportunity to further explore the role that students' religious beliefs played in their informal reasoning process. One of the advantages of using an interview is that the students could seek more detail about the dilemmas presented if they did not fully understand the science concerned, thereby allowing students to demonstrate their reasoning patterns from an informed standpoint. Likewise, the interviewer was able to clarify any alternative views held by the students, if this was appropriate, and also ask probing questions to elicit more detailed responses. The use of focus groups containing five to six participants was an appropriate format to take in these interviews because, as Creswell (2008, p. 226) comments, the use of "focus groups are advantageous when the interaction among interviewees will likely yield the best information", and "when the time to collect information is limited". The opportunity to listen to other students' responses allowed for more detailed data to be obtained regarding students' reasoning because they had the opportunity to evaluate and respond to the views of their peers. Also, as only a limited time frame was available, this format allowed for interview data to be collected from more students than if one-on-one interviews were conducted.

The interview questions covered four areas of biotechnology, and were adapted from Sadler and Zeidler's (2005a) US study involving college students. Students were asked questions about genetically modified food, the use of pre-implantation genetic screening, the cloning of animals, and the cloning of humans. Each topic was posed in the form of an ethical dilemma. The generalised format of the interview protocol is described in Figure 3.3

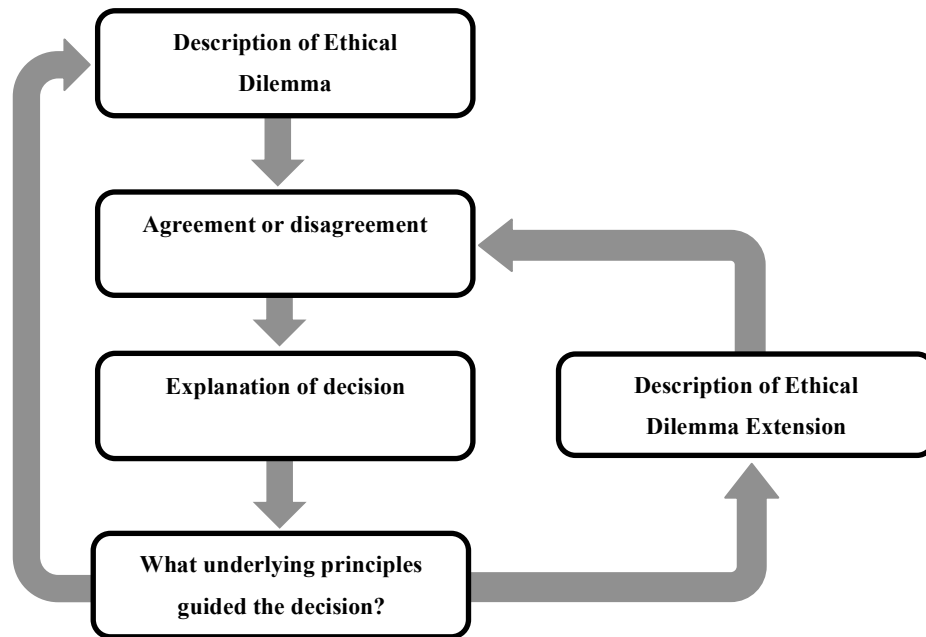


Figure 3.3 *Generalised format of the interview protocol.*

After a short description to introduce the ethical dilemma, read by the interviewer, a series of questions was asked to elucidate the students' reasoning about the issue. Students were first asked whether they agreed with using the technology as described, and were then asked to provide an explanation for their decision. To aid students in providing an explanation, students were asked to describe how they would convince a friend of their opinion. Students were then asked if there were any underlying principles that they used when making their decision. This was done to provide students with additional opportunity to identify possible faith-based principles or arguments relevant to their decision. The interview protocol also provided the students with an extension to the ethical dilemma, and students were again asked to explain whether they agreed with the technology or not, and what principles they were using to make that decision. The extension ethical dilemmas were deliberately



designed to either make the application more likely to be rejected by those who had accepted it, or to provide a situation where the technology would be more likely to be accepted by those who had rejected it. One example of this is the questions that were asked about pre-implantation genetic screening (PGS). After asking whether it would be acceptable to use PGS to select a genetic match for a sibling who requires a bone marrow transplant, the extension question asked students if they would use the same technology to select for intelligence. In this way the context within which a technology was used could be explored and, through this, the underlying ethical issues concerning the technology could be identified, along with the reasoning used to reach conclusions about the technology.

A full description of the questions used in the interviews is provided in the interview protocol located in Appendix B.

### **3.4 ADMINISTRATION OF QUESTIONNAIRE AND INTERVIEWS**

#### **3.4.1 Administration of Questionnaire**

All senior students in the three participating schools were asked to complete the questionnaire, with most individuals present on the day choosing to participate. The researcher personally attended each of the three schools to coordinate the completion of the questionnaires. The questionnaire was completed in class time, after communication with both the school principal and the class teacher to find a time that was convenient for the teacher and which would minimise disruptions to the students' learning. Prior to attending each school, information sheets and consent forms were given to all potential participants; a copy of each is presented in Appendix C. The information sheet outlined the questions that would be asked, along with the students' rights and the researcher's responsibilities. The completed consent forms were collected by a staff member at each school and returned to the researcher. Before completing the questionnaire, the students were provided clear verbal instructions that highlighted the purpose of the study, the rights of the students, and the responsibilities of the researcher. Students were provided with one class period to complete the questionnaire, about fifty minutes. On completion, the students had quiet work they were asked to continue with.

### **3.4.2 Administration of Interviews**

Participants for the focus group interviews were selected from those students who indicated their willingness to participate in further research at the time of completing the questionnaire. The interviews were held at the end of the year after Year 12 students had finished school. Therefore, only Year 11 students were available for the interviews. The students were placed into four focus groups according to the subjects they had taken in year 11. There were two groups of students who had studied Biology with six students in each, one group of five students who had studied a science subject other than biology, and one group of six students who had studied no science subjects. Students were informed of the time and location of their interview and provided with information outlining the questions they would be asked along with their rights and the researchers' responsibilities. A consent form, a copy of which can be located in Appendix C, accompanied the letter.

Each interview session was allocated one normal class period, approximately fifty minutes, which provided enough time to complete the thirty- to forty-minute interviews in a relaxed manner, as well as some time for students to ask further questions during refreshments. Each interview was digitally recorded and stored as an MP3 file for analysis. The students were informed that the interview was being recorded and given the opportunity to withdraw if they chose. Each student stated his or her name at the commencement of the interview to assist with transcription.

## **3.5 ANALYSIS OF DATA**

### **3.5.1 Coding**

The quantitative data obtained from sections 2, 3 and 4 of the questionnaires was first entered into a spreadsheet, demographic information (Section 1) was numerically coded and appropriate formulas were used to reverse code those items that were asked in the negative. The subsequent data set was transferred to the PASW software package where incomplete data was removed ready for analysis.

The qualitative data from the questionnaire (Section 4 of the BARBQ) was typed up using a word processor for further analysis. Each comment was coded according to Sadler and Zeidler's (2005a) patterns of informal reasoning. Bold font was used to identify rational informal reasoning, italicised for intuitive reasoning and underlined for emotive informal reasoning. Comments that made reference to God or religious

ideas were marked with blue font, which was changed to red if in addition the comment provided reference to specific Christian or faith principles that were incorporated into the students' informal reasoning process. Comments that made specific reference to a disbelief in God or were negative towards religion or religious belief were highlighted in yellow.

### **3.5.2 Quantitative Analysis of Student Questionnaires**

Using the statistical software PASW, a numerical value for each strand or scale of the BARBQ<sub>quant</sub> was obtained for individual students by averaging the Likert values for all the questions in a strand or scale. True or False data was allocated a value corresponding to the number of responses answered correctly. The instrument was validated by calculating the scale mean, standard deviation, internal consistency (Cronbach Alpha reliability), and the ability to differentiate between scales (ANOVA results). The item mean for each scale in Section 2 and Section 3 of the BARBQ was compared with the demographic data obtained in Section 1 of the BARBQ: gender, year level, school, and science subjects taken. This was done so that the effects of those variables could be identified and, if necessary, accounted for in the analysis of the impact of Christian religious belief on students' attitudes towards biotechnology. To answer Research Question 1, the associations between religious beliefs and attitudes towards biotechnology were obtained by performing correlation and regression analysis. The associations between the measures of religious belief and the ethical dilemmas in Section 4 of the BARBQ<sub>qual</sub> were also calculated using the Likert scale responses completed with each of the questions in Section 4.

Two additional scales were formed; the Christian Worldview Scale (CWS) and the Combined Attitudes Towards Biotechnology Scale (CATBS), using the corresponding data obtained from Section 2 and Section 3 of the BARBQ. Validation of the two new scales, CWS and CATBS, was achieved by calculating the scale mean, standard deviation, internal consistency (Cronbach Alpha reliability), and the ability to differentiate between scales (ANOVA results).

Utilising the newly formed scale measuring Christian worldview, CWS, two groups of students were formed, differentiated according to those who recorded a low level of religious belief and those who recorded a high level of religious belief as measured by the CWS. Mean, standard deviation, *t*-tests and effect sizes were

calculated for students' concerns about biotechnology (Section 2 of the BARBQ: affective strand) and their acceptance of the biotechnologies presented in the dilemmas (Section 4 of BARBQ), so that the difference between levels of religious belief could be examined.

### **3.5.3 Analysis of Informal Reasoning and Reasoned Religious Belief Level**

To answer Research Question 2, students' mode of informal reasoning was tabulated according to their level of religious belief so that differences in patterns of informal reasoning could be more easily identified. The students' Reasoned Religious Belief Level (RRBL) was developed to describe the student's use of religious or faith principles in their informal reasoning. This included negative attitudes towards religion, no mention of religion, a reference only to religion, or an argument based on religious principles. This data was tabulated for each ethical dilemma so that the level of religious arguments could be compared across the dilemmas.

### **3.5.4 Analysis of Ethical Arguments**

Qualitative analysis of the students' extended responses to Section 4 of the BARBQ was performed prior to the analysis of the interview data. The questionnaire responses were sorted according to whether the students scored high or low on the Christian World View Scale (CWS). A description of how the students were allocated into the high level of religious belief group or the low level of religious belief group is described in Section 4.6. The responses made by students who scored high in the CWS were selected for this part of the study to better focus on the third research question, which asked how students' Christian religious beliefs are incorporated into their informal reasoning about biotechnology. Those students scoring low in the CWS were also examined as a comparison with the more religious cohort of students. Using the concerns about biotechnology identified in the literature as a guide, the students' questionnaire responses were read through multiple times and common ethical arguments were identified in the students' informal reasoning about biotechnology issues. The interviews were also listened to multiple times and those sections that provided further insight into the ethical arguments identified in the questionnaire data were transcribed and incorporated into the analysis of the qualitative data. After a review of the common ethical arguments identified, those ethical arguments that had similar overarching ideas were combined into one ethical argument; in this way, the ethical arguments 'God is creator of the plants' and 'God

is creator of humans' were combined into a single ethical argument, 'God is creator'. Those ethical arguments that had two distinct ideological ideas were separated into two arguments, so that ethical arguments involving the conflict between science and religion were separated into two ethical arguments, 'religion limits science' and 'science disregards faith'. After the review, a total of 12 ethical arguments were identified: 'health benefits', 'social justice', 'health concerns', 'not natural', 'playing god', 'God is Creator', 'God's will', 'human embryo', 'uniqueness', 'slippery slope', 'religion limits science' and 'science disregards faith'.

### **3.5.5 Statistical Analysis of Ethical Arguments**

The ethical arguments identified while exploring the students' questionnaire extended responses were subjected to statistical analysis. To achieve this, all of the responses were once again reviewed and the responses to each of the ethical dilemmas were analysed for the inclusion of the ethical arguments. The statistical software package PASW was used to calculate the frequency of the ethical arguments for each question. To better understand the attitudes and beliefs of the students using the ethical arguments, the differences in attitude towards biotechnology (CATBS) and level of Christian worldview (CWS) were calculated (*t*-test) for those students who used a particular ethical argument and those students who did not use the ethical argument.

## **3.6 ETHICAL CONSIDERATIONS**

This study involved research that required minors to complete a questionnaire and participate in an interview that involved questions some students may find personal. In addition, some of the participants were also students of the researcher. In recognition of these concerns, a number of precautions were taken.

Principals, teachers, parents and students were fully informed of the purpose of this research, along with the potential risks and benefits, before any data was collected. All stakeholders were provided with an information sheet and consent forms, which clearly stated the purpose of the questionnaire and interview; Appendix C contains a copy of the information sheets and consent forms provided to the different stakeholders. Students were provided an opportunity to ask questions about the research and both students and parents were reassured that they could withdraw from the study at any time without prejudice or negative consequences. The participants

were also informed that no part of the research would contribute towards assessment for schoolwork. Data collection was planned in consultation with the school principals and the class teachers to minimise the disruption to the normal teaching-learning program. The school chaplain was available to talk to the students about any concerns they had after completing the questionnaire.

Privacy and confidentiality were maintained during the collection of the data since students were not required to identify themselves on the questionnaires. Students indicated their willingness to participate in a further study (for the interviews) on a separate form that was collected independently of the questionnaire, as were the permission forms. Each student was given a unique numerical code for data management purposes only; this was allocated once the questionnaire had been completed. The numbers were not recorded against names of students, thereby guaranteeing anonymity. The recordings of the interviews contained the participants' first name, to assist with transcription. Whilst the full names of the students interviewed were known to the researcher they have not been included as part of the reporting process and will remain anonymous throughout the report.

### 3.7 SUMMARY OF CHAPTER

The purpose of this study was to explore the role of Christian religious beliefs in students' attitudes towards biotechnology in Victorian Christian Schools. Two instruments were used to gather students' responses. The Biotechnology Attitudes and Religious Belief Questionnaire (BARBQ) was developed by combining and modifying six previously documented instruments, and focus group interviews were utilised to provide supplementary data to the questionnaires.

Data was collected from three Christian schools in Victoria, Australia, all from the same school system. A total of 177 valid responses were completed.

The quantitative data underwent statistical analysis with the software package PASW to validate the BARBQ, determine the correlation between religious belief and attitudes towards biotechnology, the effects of religious belief on students' patterns of informal reasoning about biotechnology, and the frequency in which they used religious reasoning in their responses. Qualitative data was also examined and the ethical arguments that were incorporated into students' informal reasoning were identified.

## Chapter 4

### RESULTS AND ANALYSIS FOR RESEARCH QUESTION 1

#### 4.1 OVERVIEW OF RESULTS

This study has used both qualitative and quantitative methods to explore the role of Christian religious beliefs in students' attitudes and reasoning with respect to biotechnology so that science educators can better understand the cultural beliefs that shape students' thinking and attitudes about contentious issues in biology. The results of this research are presented across three chapters. Chapter 4 addresses Research Question 1, and data is presented that shows that Christian religious belief is a predictor of negative attitudes towards many aspects of biotechnology. Chapter 5 addresses Research Question 2 and provides evidence that a Christian religious belief can influence a student's informal reasoning about socioscientific issues. The third research question is addressed in Chapter 6 and explains how religious beliefs are incorporated into students' informal reasoning about biotechnology. Chapter 6 presents the analysis of the *BARBQqual* by providing a detailed description of the ethical arguments used by students in responding to biotechnology dilemmas. This chapter also applies a statistical treatment to the ethical arguments presented, and show how the use of these ethical arguments differs between students with a high level of religious belief and those with a low level of religious belief. In addition, Chapter 6 presents data that shows the frequency with which students use faith-based reasoning in their responses to biotechnology issues.

#### 4.2 CHAPTER OVERVIEW

Research Question 1 addressed the issue of whether religious belief was a predictor of student attitudes towards biotechnology. In addressing this question, this chapter starts with a description of how the data was prepared for analysis so that the reproducibility of the results could be enhanced. This is followed by a summary of the demographic data so that this research can be put into a social context and therefore aid in the generalisability of the research. The chapter then continues with the validation of the *BARBQquant*, the instrument used in the study to measure students' biotechnology attitudes and their religious belief. A description is provided of the procedure used to divide the sample into those students who have a high level

of Christian religious belief and those with a low level of Christian religious belief. Descriptive statistics provide an overall picture of these two groups.

Four sections are then presented that provide evidence that religious belief is a predictor of attitudes towards biotechnology. This includes a description of the role that gender, subjects, school and year level play in the relationship between measures of a Christian worldview and student attitudes towards biotechnology, and the associations between measures of a Christian worldview and attitudes towards biotechnology. The next section presents the associations between the ethical dilemmas and measures of a Christian worldview, and is followed by a presentation of the results of students' concerns about biotechnology and measures of a Christian worldview. Each section addressing the results of Research Question 1 is concluded with a summary of the research findings and the chapter concludes with a summary of the key findings presented in Chapter 4.

#### 4.3 DATA PREPARATION

While entering data from the Biotechnology Attitudes and Religious Belief Questionnaire (BARBQ) into a statistical analysis package (SPSS), the questionnaire results were visually scanned for abnormal responses (e.g. the same response given for all questions). These questionnaires with abnormal responses, along with those for which respondents had completed very few of the items, were removed from the data set. A total of 4 questionnaires out of 181 were removed from the data set.

The Cognitive strand of the BARBQ had two scales, biology and genetics (questions 1 to 9) and biotechnology (questions 10 to 26), which utilised true or false questions. The students' responses to these questions were graded with a correct answer being recorded as a one while incorrect answers were recorded as a zero. The three cognitive scales, Biology and Genetics, Biotechnology, and Beliefs About Biotechnology, as well as the three affective scales (Emotions, Inevitability and Concerns), and also the two behavioural scales (GM Food Intentions and Medical Intentions), were all analysed separately. The bivariate items used in the scales Biology and Genetics, and Biotechnology were averaged, with each student receiving a score with a possible range of zero to one. For the remainder of the attitudes towards biotechnology scales, the items making up that scale were averaged to provide a possible score ranging from one to five. The exception was the ethical



dilemmas, Section 4 of the questionnaire, which was averaged to form a value between one and six because it utilised a six-point Likert response (as discussed in Section 3.3.2.2). To provide an easier comparison with other scales in the BARBQ, the biotechnology ethical dilemmas were converted to a scale of one to five. All responses were recorded so that a low score corresponded to a low level of support or understanding of biotechnology and a high score corresponded to a high level of support or understanding of biotechnology.

The two scales of religiosity (Behavioural and Religious Salience) were not analysed separately because of the small number of questions that made up each scale; instead, these questions were combined and the strand labelled 'Religiosity'. After combining the two measures of religiosity, the three strands of a Christian worldview (Religiosity, Christian Orthodoxy and Biblical Literalism) were treated as individual scales. As with previous scales, the items within each of the three Christian Worldview scales were averaged, with scores ranging from a possible one to five, reflecting the Likert response options for the items in these scales. All responses were recorded such that a low score corresponded to a low level of religious belief and a high score corresponded to a high level of religious belief.

#### 4.4 DEMOGRAPHIC DATA

After removing from the data set those questionnaire responses that were unable to be used, a total of 177 questionnaire responses were available for analysis. This included 72 male participants, 95 female participants, and 10 students who did not indicate their gender on the questionnaire. It was decided to include in the data set questionnaires that were missing gender, age, or grade data, because this did not relate directly to the research question. The researcher recorded the school data, which identified what school the participant attended.

The frequency of males and female respondents was collated for the School attending, Age, Grade and the subjects studying. This data is presented in Table 4.1.

#### 4.5 VALIDATION OF THE BARBQ

The data collected from 177 student responses was used to test the internal consistency reliability using Cronbach's alpha coefficient (Cronbach, 1951) of each of the eight biotechnology attitude scales and the three religious belief scales. These results are reported in Table 4.2. The reliability of the scales of Biology and Genetics

and Beliefs About Biotechnology were less than the acceptable level of 0.6, indicating a low level of reliability (De Vellis, 1991). Biology and Genetics had an alpha reliability of 0.27 and Beliefs about Biotechnology had a reliability of 0.47. Although reliability was low for Beliefs about Biotechnology, provided that results using this scale are treated with appropriate caution, this scale might offer some insight into the research question. For this reason, the Beliefs About Biotechnology scale was kept in the study; however, the Biology and Genetics scale was removed from the study. The reliability for Biotechnology was marginal at 0.58 (De Vellis, 1991) and also needs to be treated with some caution. The remainder of the scales showed a similar or increased reliability compared to previous studies, ranging from 0.73 to 0.91, and were considered acceptable (De Vellis, 1991). The reliability of each scale measured in previous studies is discussed in the methodology chapter (Section 3.3) and summarised in Table 3.3.

Table 4.1 *Sample Sizes*

Demographic data	Male	Female	Total <sup>a</sup>
<b>School</b>			
School 1	36	62	104
School 2	30	23	57
School 3	6	10	16
<i>Total</i>	72	95	177
<b>Age</b>			
16	36	35	76
17	23	40	65
18	11	20	32
19	1	0	1
Not provided	1	0	3
<i>Total</i>	72	95	177
<b>Grade</b>			
Yr11	41	41	88
Yr12	31	54	86
Not provided	0	0	3
<i>Total</i>	72	95	177
<b>Subjects</b>			
Biology	21	43	68
Physics	25	5	34
Chemistry	24	30	56
Psychology	17	47	67
Religion and society	72	95	177

Note. Total sample,  $N = 177$ ; male  $n = 72$ ; female,  $n = 95$ ; gender not provided,  $n = 10$

<sup>a</sup>Includes  $n = 10$  students that did not indicate gender.

Table 4.2 *Scale Mean, Standard Deviation, Internal Consistency (Cronbach's Alpha Reliability) and Scale Mean Correlation for the BARBQ*

BARBQ <sub>quant</sub> Scale	No. Items	Mean	SD	Alpha Reliability	Mean Correlation
<b>Attitudes About Biotechnology</b>					
<u>Cognitive</u>					
Biology and Genetics <sup>a</sup>	9	0.74	0.15	0.27	0.11
Biotechnology <sup>a</sup>	16	0.74	0.15	0.58	0.11
Beliefs About Biotechnology	5	3.30	0.57	0.47	0.17
<u>Affective</u>					
Emotions	13	2.65	0.59	0.82	0.18
Inevitability	9	3.12	0.58	0.73	0.21
Concerns	8	2.83	0.88	0.82	0.08
<u>Behavioural</u>					
GM Food Intentions	5	3.09	0.86	0.85	0.22
Medical Intentions	4	3.51	0.90	0.77	0.15
<b>Christian Worldview</b>					
Christian Orthodoxy	6	4.13	1.07	0.91	0.01
Biblical Literalism	15	3.91	1.07	0.97	0.03
Religiosity	4	3.27	1.25	0.89	0.04
<b>Combined Scales</b>					
CATBS	7	15.23	2.7	0.75	0.76
CWS	3	3.75	1.01	0.86	0.92

Note. *N* = 177

<sup>a</sup>Bivariate data (incorrect = 0, correct = 1)

The scale mean correlation of the Attitudes About Biotechnology and Christian Worldview scales ranged from 0.01 to 0.22, indicating that the items used in the instrument tend to correlate much more with items in the same scale than with items on other scales. The results recorded in Table 4.2 suggest that the BARBQ provided good internal consistency, reliability and discriminant validity for the affective and behavioural domains of attitudes towards biotechnology, as well as all three scales measuring students' Christian worldview (Religiosity, Christian Orthodoxy and Biblical Literalism). Measures of the Cognitive domain of Attitudes Towards Biotechnology, however, demonstrated questionable reliability.

To investigate the role that students' religious beliefs played in their reasoning about biotechnology, it was necessary to develop two additional scales, one to describe a student's overall attitude towards biotechnology and another the combined level of Christian religious belief (Christian worldview). To achieve this, the three affective

and two behavioural scales in the Biotechnology strand of the BARBQ were averaged. The two cognitive strands, Biotechnology, and Beliefs About Biotechnology, were not included because of their low reliability and the results of factor analysis (not reported here). The resulting score was named the Combined Attitudes Towards Biotechnology Scale (CATBS). The combined measure of religious belief was named the Christian Worldview Scale (CWS), and was calculated by averaging the three strands of Christian Orthodoxy, Biblical Literalism and Religiosity. While it is recognised that, by combining these scores, some of the unique contributions that each scale provided would be lost, the two combined scales still provide a robust measure of the students' attitude towards biotechnology that incorporates the cognitive, affective and behavioural aspects through which attitudes are developed, as well as the three measures of a religious worldview, which include core beliefs (Christian Orthodoxy) fundamentalism (Biblical Literalism) and personal religious behaviour (Religiosity). Because the averages of the individual strands were summed to generate the two combined scales, each individual strand provided an equal contribution to the final combined scale. In this way, the individual strands that contained more items did not mask the contribution of the other strands.

To ascertain the internal consistency of the two combined scales, Cronbach's alpha coefficient was calculated (Cronbach, 1951). The CWS was found to be highly reliable ( $\alpha = 0.86$ ) and the CATBS was also reliable, with a Cronbach's alpha of 0.75. The reliability of both scales is reported in Table 4.2. When correlated against the scales they contain the scale mean correlation for the CATBS and CWS is 0.76 and 0.92, respectively. A scale mean correlation of 1.00 would indicate a perfect correlation, and so these values indicate that the CATBS and CWS are closely correlated to each of the scale items they contain, and therefore provide good overall scales for religious belief and attitudes towards biotechnology. It should be noted that scale reduction analysis probably would improve the reliability of these scales, and this may be beneficial for future studies. However, for the current study, the methodological integrity found in incorporating the different aspects of attitude and religious belief was considered to be of greater importance, and therefore no additional scale reduction was performed.

#### 4.6 DIVISION OF SAMPLE INTO LEVELS OF RELIGIOUS BELIEF

In order to further examine the effects of religious belief on both students' attitudes towards, and their reasoning about, biotechnology, it was necessary to determine those students who had a relatively low level of Christian religious belief and those students who had a high level of Christian religious belief. To obtain a combined scale of religious belief, the three religious belief scales were averaged to obtain the Christian Worldview Scale (CWS). Because a student's score on the CWS could range from 1 to 5, it was necessary to select a cut-off value to divide the sample into those students with a high level of religious belief and those students with a low level of religious belief. When responding to the questions that made up the CWS, a score of 4 and 5 corresponded to the student agreeing or strongly agreeing with a statement indicative of a Christian worldview. To encompass all those students who, on average, agreed or strongly agreed with the key elements of a Christian worldview, those students scoring above 3.5 on the CWS were considered to have a high level of religious belief. Likewise, those students who scored less than 2.5 out of a possible 5 on the CWS were deemed to have a low level of Christian religious belief because, on average, they disagreed or strongly disagreed with key elements of most Christian worldviews. This delineation provides a clearer distinction between the two groups by eliminating from the data set those students who may not have been fully committed to the Christian worldview, or who, while possibly having religious belief, did not align closely with traditional Christian beliefs or interpretations of the Bible.

Descriptive statistics were performed for the two groups consisting of high level of religious belief and low level of religious belief, with the results reported in Table 4.3. As indicated in this table, 21 students were grouped as having a low level of religious belief, with a mean score on the CWS of 1.76, and a standard deviation of 0.34. Substantially more students ( $n = 117$ ) were grouped as having a high level of religious belief, with a mean and standard deviation of 4.40 and 0.43, respectively, on the CWS.

Table 4.3 *Descriptive Statistics for Students Defined as Having Low and High Levels of Religious Belief Showing Mean, Standard Deviation, Kurtosis and Skew*

	Level of Religious Belief	
	Low	High
Sample size	21	117
Mean	1.76	4.4
Standard Deviation	0.34	0.43
Kurtosis	-0.96	-0.53
Skew	-0.27	-0.72

#### 4.7 EFFECTS OF GENDER, SCHOOL, SUBJECT AND YEAR LEVEL

In order to adequately interpret the relationship between a Christian worldview and attitudes towards biotechnology, it was necessary to examine the effects of the four variables collected as part of the demographic data, gender, school, science subjects taken and year level because they might play a role in both students' attitudes towards biotechnology and students' religious beliefs.

##### 4.7.1 Analysis of the effects of Gender, School, Subject and Year Level

The item means for each scale on the BARBQ was compared between genders, schools, science subjects taken and year levels. The results of this analysis are presented in Appendix D, which show the Average Item Mean, Average Item Standard Deviation, Effect Size and the results of a *t*-test for each of the variables. A summary of these results is shown in Table 4.4, and shows only the statistically significant differences from this analysis. Year level, which had no statistically significant differences, is not reported here.

##### 4.7.2 Summary of the Effect of Gender, Subjects, School and Year Level

An examination of gender differences shows statistically significant differences for 8 out of 11 scales. Beliefs About Biotechnology, Emotions, Christian Orthodoxy and Biblical Literalism have statistically significant gender differences ( $p < 0.001$ ). Gender differences for Inevitability, GM Food Intentions, and Religiosity was significant at  $p < 0.01$  and gender differences in Concerns was significant at  $p < 0.5$ . The results show that, within the sample population, females show a higher level of religious belief than their male counterparts. Provided that a relationship between religious belief and attitudes to biotechnology exists, then the decreased acceptance of biotechnology by females may be a consequence of the females' increased level of religious belief. These results therefore suggest that gender differences should be

considered when assessing the overall relationship between religious belief and students' attitudes towards biotechnology.

Table 4.4 *Summary of Three-way ANOVA and t-Tests for Differences (Gender, School and Subject) Showing Significance and Variable With the Greater Item Mean*

BARBQ <sub>quant</sub> scale	Gender	School	Subject
<b>Attitudes Towards Biotechnology</b>			
<u>Cognitive</u>			
Biotechnology		$p < 0.01$ School 1	$p < 0.001$ Chemistry
Beliefs About Biotechnology	$p < 0.001$ Male		
<u>Affective</u>			
Emotions	$p < 0.001$ Male		
Inevitability	$p < 0.01$ Male		
Concerns	$p < 0.05$ Male		$p < 0.01$ no Biology
<u>Behavioural</u>			
GM Food Intentions	$p < 0.01$ Male		
Medical Intentions			
<b>Christian worldview</b>			
Christian Orthodoxy	$p < 0.001$ Female		$p < 0.001$ Chemistry
Biblical Literalism	$p < 0.001$ Female		$p < 0.05$ Chemistry
Religiosity	$p < 0.01$ Female		$p < 0.05$ Biology

Note. Total sample,  $N = 177$ ; males,  $n = 72$ ; females,  $n = 95$ ; Biology,  $n = 68$ ; no Biology,  $n = 109$ ; Chemistry,  $n = 56$ ; School 1,  $n = 104$ .

Statistically significant differences were found between students studying Biology, as well as those studying Chemistry, when compared to those students who were not enrolled in these subjects. No statistically significant differences were found when comparing either Physics or Psychology students to the remaining cohort. For the subject of Biology, two out of ten scales have statistically significant differences between those that were taking a Biology subject and those that were not. Differences between taking Biology and not taking Biology were statistically significant for Concerns ( $p < 0.01$ ) and Religiosity ( $p < 0.5$ ), with Biology students being more concerned about biotechnology and more religious. For the subject of Chemistry, three out of ten scales have statistically significant differences between those students that were studying Chemistry and those that were not. Differences between students taking Chemistry and those who did not take a Chemistry class

were statistically significant for the scales of Biotechnology, and Christian Orthodoxy ( $p < 0.001$ ) and Biblical Literalism ( $p < 0.5$ ). The Chemistry students therefore demonstrated, on average, a better understanding of biotechnology and a higher level of religious belief.

No statistically significant differences were found between students in Year 11 and those in Year 12. While it may be expected that Year 12 Biology students at least would score higher in the first strand of Attitudes Towards Biotechnology section of the BARBQ (Cognitive: Biotechnology), it should be noted that the questionnaire was taken prior to the Year 12 students completing the units on genetics and gene technology; this would result in both year levels having a similar knowledge base about the topics examined in the biotechnology attitudes strand of the questionnaire.

#### **4.7.3 Correlation between Biotechnology Attitudes and Belief by Gender**

It was shown in Section 4.7.2 that there was a statistically significant difference between genders in areas of religious belief and some measures of attitude towards biotechnology. To determine if gender had any significant effect on the relationship between religious belief and attitudes towards biotechnology, correlational analysis was performed between the three measures of religious belief and the seven measures of attitudes towards biotechnology. Because the combined scales, CATBS and CWS, were also necessary for further analysis, the association between these two scales was calculated and the results reported in Table 4.5, along with the correlation between the individual scales. The analysis utilised pairwise deletion for missing data, which resulted in a different sample size across the strands for male and female students. The sample size for each strand is identified in Table 4.5.

#### **4.7.4 Summary of Biotechnology Attitudes and Beliefs by Gender**

For the Christian Orthodoxy scale, correlations with Beliefs About Biotechnology and GM Food Intentions were statistically significant for males ( $p < 0.01$ ). The correlation with Concerns was statistically significant ( $p < 0.05$ ) for females, and both genders were statistically significant for the correlation with Emotions (male  $p < 0.01$ , females  $p < 0.05$ ) and the CATBS (male  $p < 0.01$ , females  $p < 0.05$ ).

Correlations for the Biblical Literalism scale was statistically significant in males when correlated against Emotions ( $p < 0.01$ ), Inevitability ( $p < 0.01$ ) and GM Food Intentions ( $p < 0.05$ ) and both males and females correlated statistically significantly



with Beliefs About Biotechnology (male  $p < 0.01$ , female  $p < 0.05$ ), Medical Intentions (male  $p < 0.05$ , females  $p < 0.05$ ), and the CATBS (male  $p < 0.01$ , females  $p < 0.01$ ).

The correlations for Religiosity was statistically significant ( $p < 0.05$ ) for males when compared with Beliefs About Biotechnology and Medical Intentions, while females correlated statistically significantly ( $p < 0.05$ ) for Emotions. Both genders correlated with statistical significance for concerns ( $p < 0.05$ ) and the CATBS (male  $p < 0.01$ , females  $p < 0.05$ ).

For both males and females, the CWS had statistical significant correlations with: Emotion (male  $< 0.01$ , females  $< 0.01$ ), Inevitability (male  $p < 0.01$ , females  $p < 0.05$ ), Concerns (male  $p < 0.05$ , females  $p < 0.05$ ), Medical Intentions (male  $p < 0.01$ , females  $p < 0.05$ ), and the CATBS (male  $p < 0.01$ , females  $p < 0.01$ ). In addition, males correlated with statistical significance for Beliefs About Biotechnology ( $p < 0.01$ ) and GM Food Intentions ( $p < 0.05$ ).

Table 4.5 *Pearson's Correlation of Male and Female Students for the Christian Worldview Scales, and Attitude Towards Biotechnology Scales*

Attitudes Towards Biotechnology	Christian Orthodoxy		Biblical Literalism		Religiosity		CWS	
	Male <sup>a</sup>	Female <sup>b</sup>	Male <sup>c</sup>	Female <sup>d</sup>	Male <sup>e</sup>	Female <sup>f</sup>	Male <sup>g</sup>	Female <sup>h</sup>
<u>Cognitive</u>								
Biotechnology	-0.12	0.12	-0.12	0.10	-0.07	-0.08	-0.07	0.06
Beliefs About Biotechnology	-0.34**	-0.14	-0.36**	-0.26*	-0.25*	-0.02	-0.36**	-0.13
<u>Affective</u>								
Emotions	-0.38**	-0.25*	-0.36**	-0.18	-0.12	-0.27*	-0.33**	-0.27**
Inevitability	-0.45**	-0.16	-0.37**	-0.19	-0.19	-0.15	-0.34**	-0.21*
Concerns	-0.22	-0.21*	-0.21	-0.19	-0.26*	-0.25*	-0.26*	0.25*
<u>Behavioural</u>								
GM Food Intentions	-0.24*	-0.07	-0.28*	-0.11	-0.20	-0.02	-0.28*	-0.07
Medical Intentions	-0.23	-0.17	-0.26*	-0.26*	-0.37*	-0.14	-0.33**	-0.21*
<b>CATBS</b>	-0.36**	-0.25*	-0.38**	-0.27**	-0.35**	-0.23*	-0.41**	-0.28**

Note. <sup>a</sup> $n = 71$ . <sup>b</sup> $n = 93$ . <sup>c</sup> $n = 70$ . <sup>d</sup> $n = 93$ . <sup>e</sup> $n = 68$ . <sup>f</sup> $n = 86$ . <sup>g</sup> $n = 72$ . <sup>h</sup> $n = 95$

\* $p < 0.05$ , \*\* $p < 0.01$

#### **4.7.5 Key Findings for Biotechnology Attitudes and Beliefs by Gender**

Although gender is clearly a mediating factor in the relationship between attitudes towards biotechnology and religious belief, the evidence provided in this analysis suggests that a statistically significant relationship does exist between religious belief and attitudes towards biotechnology regardless of gender. Of particular note is the correlation between the CWS and the CATBS, which confirms that, for both genders, religious belief is negatively correlated with attitudes towards biotechnology. From this analysis, it can be concluded that the association between gender and biotechnology, and the association between gender and religious belief that has been described in the literature and confirmed in this study, does not critically undermine further analysis of the relationship between religious belief and attitudes about biotechnology. Therefore, the separate treatment of genders during statistical analysis was not necessary in this study.

#### **4.8 CHRISTIAN WORLDVIEW AND BIOTECHNOLOGY ASSOCIATIONS**

To determine the associations, if any, between religious beliefs and students' attitudes towards biotechnology, correlation and regression analyses were performed using the data from the BARBQ. To determine the predictive power of religious belief in determining attitudes towards biotechnology these two tests were performed between the individual strands of the Attitudes Towards Biotechnology section of the BARBQ and each scale (or strand) measuring students' Christian Worldview.

##### **4.8.1 Associations Between CWS and CATBS**

In order to obtain an initial assessment of the association between religious belief and attitudes towards biotechnology, the correlations between the two combined scales, the Combined Attitudes Towards Biotechnology Scale (CATBS) and the Christian Worldview Scale (CWS), were calculated. The CATBS was a combination of the three affective and two behavioural strands in the Attitudes Towards Biotechnology section of the BARBQ, while the CWS combined the three scales of Christian religious belief (Religiosity, Christian Orthodoxy, and Biblical Literalism). The results of correlation and multiple regression analyses are shown in Table 4.6.

Table 4.6 *Relationship of Christian Worldview Scale (CWS) and Combined Attitudes Towards Biotechnology Scale (CATBS)*

Scale	Statistic	Relationship with CATBS
CWS	$r$	-0.381
	$R^2$	0.148
	Significance	$p < 0.01$
Note. $N = 177$ ; CATBS = Combined Attitudes Towards Biotechnology Scale; CWS = Christian Worldview Scale		

#### 4.8.2 Summary of Associations Between CWS and CATBS

A statistically significant correlation ( $r = -0.381$ ,  $p < 0.01$ ) was found between the CATBS and the CWS, and a regression analysis between these two scales also showed a statistically significant ( $p < 0.001$ ) association, with a regression weight of -0.385 and  $R$  squared of 0.148. This supports earlier studies as discussed in the literature review (Section 2.6.4), as well as the findings of this study presented in Section 4.7, which have suggested that individuals with a religious worldview tend to have a more negative attitude towards biotechnology.

#### 4.8.3 Analysis of Associations Between Belief and Biotechnology

For a more detailed analysis of students' attitudes towards biotechnology, the associations between the three measures of religious belief and the seven scales of biotechnology attitudes were determined by conducting correlation and multiple regression analyses.

A correlation analysis of the relationship between each scale of religious belief and the seven scales of biotechnology attitudes was performed to provide information about the association between each religious belief scale and each biotechnology attitude scale. In order to provide a more complete picture of the combined influence of the correlated religious belief scales, a multiple regression analysis of the relationship between each biotechnology attitudes scale and the set of three religious belief scales was also performed. To interpret which of the individual religious belief scales provided a significant unique contribution to the variance in biotechnology attitudes, the regression weights were examined to see which ones were significantly greater than zero ( $p < 0.05$ ). The regression weights describe the influence of a particular attitude variable when all other attitude variables in the regression analysis are mutually controlled. The results of the simple correlation and regression analyses

are shown in Table 4.7.

The results of the regression analysis showed that the religious belief scales did not provide a unique contribution that was statistically significant for most of the measures of biotechnology attitudes, despite a statistically significant correlation between these scales. While it is possible that a correlation may exist without statistically significant regression results, it was suspected that, because the three religious belief scales were not independent of each other, the regression analysis might have been affected by multicollinearity (high correlation between two or more of the religious belief scales). While not limiting the overall ability of the scales to predict students' attitudes towards biotechnology, multicollinearity would limit the unique contribution to the variance in the biotechnology scales and hence limit its statistical significance. For this reason, a *post hoc* analysis was performed using a stepwise regression so that the religious belief scale, or scales, that best predicted students' attitudes towards biotechnology could be determined (Field, Miles, & Field, 2012). The results of the stepwise regression analysis are shown in Table 4.8.

#### **4.8.4 Summary of Associations: Cognitive Strand**

The correlation results for the two scales that make up the cognitive strand of attitude towards biotechnology, knowledge about biotechnology and beliefs about biotechnology, are reported in Table 4.7, along with the results of a regression analysis. Table 4.8 shows the results of a stepwise regression for these two scales.

##### **4.8.4.1 Knowledge About Biotechnology**

Correlations for Biotechnology revealed no statistically significant association between student understanding of biotechnology and the religious belief scales. Standardised regression weights were calculated to provide information regarding the unique contribution of each religious belief scale to Knowledge about Biotechnology. Table 4.7 shows that, out of three scales, two have statistically significant associations with knowledge about Biotechnology. Regression weights for Biblical literalism is significant at  $p < 0.05$  and the regression with Christian Orthodoxy is significant at  $p < 0.01$ . When a stepwise regression was conducted to evaluate which scales provided the best prediction of knowledge about Biotechnology, the same two scales (Christian Orthodoxy and Biblical Literalism) had statistically significant regression weights, at  $p < 0.01$  for both scales. Together,

the two scales of Christian Orthodoxy and Biblical Literalism explained 5% of the variance in biotechnology knowledge. While it was unexpected to have significant regression results with no significant correlations, these two tests are measuring different relationships, the correlation identifies the strength and direction of the linear relationship between two measures, while the regression analysis provides a means of measuring the ability of a variable to predict the outcome of another. Therefore the lack of a significant correlation does not necessarily invalidate the results of the regression analysis. A number of possibilities exist to explain this result but the likely causes are a combination of suppressor variable in one or more of the religious belief scales, and multicollinearity of those scales (Field et al., 2012; R. Smith, Ager, & Williams, 1992; F. Thompson & Levine, 1997). These statistical problems that are associated with the cognitive biotechnology scale provide additional support for the decision to remove this scale from the (CATBS).

Table 4.7 *Pearson's Correlation ( $r$ ), Multiple Correlations ( $R$  and  $R^2$ ), and Standardised Regression Coefficient ( $\beta$ ) for Associations Between the Christian Worldview Scales and the Attitudes Towards Biotechnology Scales*

BARBQ Scale	Cognitive				Affective						Behavioural			
	Biotechnology		Beliefs About Biotechnology		Emotions		Inevitability		Concerns		GM food Intentions		Medical Intentions	
	$r$	$\beta$	$r$	$\beta$	$r$	$\beta$	$r$	$\beta$	$r$	$\beta$	$r$	$\beta$	$r$	$\beta$
Christian Orthodoxy	0.06	0.40**	-0.27**	0.03	-0.34**	-0.22	-0.34**	-0.26	-0.24**	-0.17	-0.20**	0.00	-0.19*	0.11
Biblical literalism	-0.04	-0.30*	-0.34**	-0.37*	-0.33**	-0.09	-0.32**	-0.09	-0.24**	0.07	-0.24**	-0.22	-0.25**	-0.26
Religiosity	-0.14	-0.17	-0.17*	0.02	-0.26**	-0.08	-0.19*	0.02	-0.28**	-0.23*	-0.14	-0.02	-0.25**	-0.16
Multiple $R$	0.25		0.34		0.35		0.33		0.31		0.24		0.29	
correlation $R^2$	0.06		0.11		0.12		0.11		0.09		0.06		0.09	

Note.  $N = 177$  students.

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$

Table 4.8 *Multiple Correlations ( $R$  and  $R^2$ ), and Stepwise Regression Analysis Results ( $\beta$ ) for Associations Between the Christian Worldview Scales and the Attitudes Towards Biotechnology Scales*

<i>BARBQ Scale</i>		Cognitive		Affective			Behavioural	
		Biotechnology	Beliefs About Biotechnology	Emotions	Inevitability	Concerns	GM food Intentions	Medical Intentions
		$\beta$	$\beta$	$\beta$	$\beta$	$\beta$	$\beta$	$\beta$
Christian Orthodoxy		0.39**		-0.34***	-0.34***			
Biblical literalism		-0.40**	-0.34***				-0.24**	
Religiosity						-0.28***		-0.25***
Multiple	$R$	0.21	0.34	0.34	0.34	0.28	0.24	0.25
Correlation	$R^2$	0.05	0.11	0.12	0.12	0.08	0.06	0.06

Note.  $N = 177$  students

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ ,

#### **4.8.4.2 Beliefs About Biotechnology**

The results of correlation analysis for Beliefs About Biotechnology were that out of the three Christian worldview scales, all correlated with statistical significance. Orthodoxy and Biblical literalism correlated with significance at  $p < 0.01$  and Religiosity correlated with significance at  $p < 0.05$ . Table 4.7 also shows the results of regression analysis. Out of three scales, the regression weight of one, Biblical Literalism, is statistically significant ( $p < 0.05$ ). The results of a stepwise regression shown in Table 4.8 shows that Biblical Literalism provided the best predictor of Beliefs about Biotechnology, and had statistically significant positive regression weights at  $p < 0.001$ . This scale was able to account for 11% of the total variance ( $R = 0.34$ ) in the Beliefs About Biotechnology scale.

#### **4.8.5 Summary of Associations: Affective Strand**

Table 4.7 reports on the correlation and regression analyses for the three scales that make up the affective strands of the attitude towards biotechnology scale: Emotions, Inevitability, and Concerns. Table 4.8 shows the results of a stepwise regression for these three scales.

##### **4.8.5.1 Emotions**

The Emotions scale was statistically significantly correlated with all three religious belief scales. Christian Orthodoxy and Biblical Literalism and Religiosity both correlated significantly at  $p < 0.01$ . The stepwise regression shown in Table 4.8 indicated that Christian Orthodoxy provided the best predictor of Emotions with a statistically significant regression weight of  $p < 0.001$ , indicating that the scale Emotions was able to account for 12% of the total variance ( $R=0.34$ ) in the Beliefs about biotechnology scale.

##### **4.8.5.2 Inevitability**

The correlations for Inevitability were statistically significant for all three of the religious belief scales. Christian Orthodoxy and Biblical Literalism correlated significantly at  $p < 0.01$ , while Religiosity correlated significantly at  $p < 0.05$ . A stepwise regression showed that Christian Orthodoxy was able to explain 12% of the variance in Inevitability ( $R=0.34$ ) and this was statistically significant at  $p < 0.001$ .



#### **4.8.5.3 Concerns**

The scale measuring concerns was significantly correlated ( $p < 0.01$ ) with all three of the religious belief scales: Christian Orthodoxy, Biblical Literalism, and Religiosity. Standardised regression weights were calculated and reported in Table 4.7, which indicates that the regression weight for Religiosity was statistically significant ( $p < 0.05$ ) for the Concerns scale. The results of a stepwise regression, shown in Table 4.8, also showed that Biblical Literalism provided the best predictor of Concerns and the regression weight was statistically significant at  $p < 0.001$ . This indicates that the Religiosity scale was able to account for 8% of the total variance ( $R=0.28$ ) in the scale measuring concerns about biotechnology.

#### **4.8.6 Summary of Associations: Behavioural Strand**

The correlation results for the two scales that make up the behavioural strand of Attitude Towards Biotechnology, GM Food Intentions and Medical Intentions, are reported in Table 4.7, along with the results of a standardised regression analysis. Table 4.8 shows the results of a stepwise regression for these two scales.

##### **4.8.6.1 GM Food**

GM Food Intentions was found to correlate statistically significantly with two out of the three religious belief scales. Correlations with Christian Orthodoxy was significant at  $p < 0.05$  and correlations with Biblical Literalism was significant at  $p < 0.01$ . A stepwise regression analysis showed that Christian Orthodoxy was able to explain 6% of the variance in students' intentions towards GM food ( $R = 0.24$ ) with a statistically significant regression weight at  $p < 0.001$ .

##### **4.8.6.2 Medical Intentions**

Correlations between Medical Intentions and the measures of religious belief were statistically significant for all three of the religious belief scales. Biblical Literalism and Religiosity correlated significantly at  $p < 0.01$  and Christian Orthodoxy correlated significantly at  $p < 0.05$ . The stepwise regression shown, in Table 4.8, indicated that Religiosity provided the best predictor of Medical Intentions with statistically significant regression weight at  $p < 0.001$ . This scale was able to account for 6% of the total variance ( $R = 0.25$ ) in the beliefs about biotechnology scale.

#### **4.8.7 Key Findings of Associations Between Beliefs and Attitudes**

The results presented in Section 4.8 show that the three Christian religious belief scales, Christian Orthodoxy, Biblical Literalism, and Religiosity, are able to provide statistical predictability for measures of senior high school aged students' attitudes towards biotechnology. However, there was not a Christian worldview scale that alone was able to provide a unique contribution to the variance in each strand of students' attitudes towards biotechnology. That is, all three strands of a Christian worldview are necessary to provide a comprehensive insight into students' attitudes towards biotechnology.

### **4.9 ASSOCIATIONS BETWEEN DILEMMAS AND RELIGIOUS BELIEF**

The four questions in Section 4 of the BARBQ (BARBQ*qual*) present students with a short paragraph that outlines specific aspects of biotechnology and how it might be applied. The examples used were: Genetically Modified Food (GM Food), Pre-implantation Genetic Screening (PGS), Reproductive Cloning (R. Clone), and Therapeutic cloning (T. Clone). While the primary intention of the BARBQ*qual* was to utilise students' written responses to explore informal reasoning and the use of religious ideas in their reasoning, students were also asked to rank on a six-point Likert scale the extent to which they agreed or disagreed with the technologies. While these questions were similar to those asked as part of the affective concerns domain of the attitude to biotechnology scale, they differed in that they placed the technologies within a context and provided additional background information. In order to provide a better comparison with data from the affective concerns scale in subsequent analyses, the six-point scale was first converted to a five-point scale. A simple correlation analysis of the relationship between each scale of religious belief and the four ethical dilemma questions was performed to provide information about the associations between scales. The results of the simple correlation analysis are shown in Table 4.9.

#### **4.9.1 Summary of Associations between Dilemmas and Religious Belief**

The results of a simple correlation between the four ethical dilemmas and the three scales of religious belief are shown in Table 4.9. As was expected, the three measures of religious belief, Christian Orthodoxy, Biblical Literalism and Religiosity, all showed a positive correlation between the scales, with a significance of  $p < 0.01$ .

Table 4.9 *Correlations Between Ethical Dilemmas and Christian Orthodoxy, Biblical Literalism and Religiosity*

Scale	Correlations					
	PGS	R. Clone	T. Clone	Christian Orthodoxy	Biblical Literalism	Religiosity
GM food	0.40**	0.21*	0.19*	-0.23**	-0.24**	-0.27**
PGS	-	0.45**	0.33**	-0.31**	-0.32**	-0.18*
R. Clone		-	0.38**	-0.26**	-0.24**	-0.19*
T. Clone			-	-0.30**	-0.36**	-0.22*
Orthodoxy				-	0.86**	0.56**
Biblical Literalism					-	0.63**

Note.  $N = 177$ . GM Food = Genetically Modified Food; PGS = Pre-implantation Genetic Screening; R. Clone = Reproductive Human Cloning; T. Clone = Therapeutic Human Cloning.

\* $p < 0.05$ , \*\* $p < 0.01$

A positive correlation was found between the four ethical dilemmas. Genetically Modified Food significantly correlated with Pre-implantation Genetic Screening at  $p < 0.01$ . Genetically Modified Food also significantly correlated with Reproductive Cloning and Therapeutic Cloning at  $p < 0.05$ . Pre-implantation Genetic Screening significantly correlated with Reproductive Cloning and Therapeutic Cloning at  $p < 0.01$ . Reproductive Cloning correlated significantly with Therapeutic Cloning at  $p < 0.01$ .

A negative correlation was found between the four dilemmas and the three scales measuring religious belief. Genetically Modified Food significantly correlated with all three of the religious belief scales, Christian Orthodoxy, Biblical Literalism and Religiosity, at  $p < 0.01$ . Pre-implantation Genetic Screening significantly correlated with all three of the religious belief scales. Christian Orthodoxy and Biblical Literalism correlated significantly at  $p < 0.01$  Religiosity at  $p < 0.05$ . Reproductive Cloning significantly correlated with all three of the religious belief scales, Christian Orthodoxy and Biblical Literalism at  $p < 0.01$  and Religiosity at  $p < 0.05$ . Therapeutic Cloning significantly correlated with all three of the religious belief scales, Christian Orthodoxy and Biblical Literalism at  $p < 0.01$  and Religiosity at  $p < 0.05$ . These results support the earlier findings in this chapter (Sections 4.6 and

4.7), which also showed a negative correlation between measures of religious belief and students' attitudes towards biotechnology.

#### **4.9.2 Key Findings of Associations between Dilemmas and Religious Belief**

The results presented in Section 4.8 show that the three Christian religious belief scales, Christian Orthodoxy, Biblical Literalism, and Religiosity, are useful in predicting the extent to which a senior high school student agrees with the application of biotechnology in genetically modified food, genetic screening, reproductive cloning, and therapeutic cloning. A higher score on the religious belief scales is associated with a greater concern for the applications of biotechnology.

### **4.10 RELIGIOUS BELIEF AND BIOTECHNOLOGY CONCERNS**

Upon examining the associations between religious belief and the affective strand of students' attitudes towards biotechnology in Section 4.8.5.3, it was noted that students' concerns about biotechnology correlated statistically significantly for students' religious beliefs. The concerns about biotechnology scale measured how worried or concerned the student felt about eight different biotechnology processes: In Vitro Fertilisation (IVF), Genetic Modification of Bacteria, Genetic Modification of Plants, Genetic Modification of Animals, Genetic Modification of Humans, Therapeutic Human Cloning, and Reproductive Human Cloning. Section 4.8 presented evidence that an association existed between measures of students' religious beliefs and their acceptance of four applications of biotechnology, presented in the form of ethical dilemmas that dealt with the socioscientific issues of Genetically Modified Food (GM Food), Pre-implantation Genetic Screening (PGS), Therapeutic Cloning (T. Clone), and Reproductive Cloning (R. Clone). To provide a more detailed examination of the affective strand with its eight technologies, as well as the four ethical dilemmas that were presented to the students, each biotechnology application and ethical dilemma was analysed independently by comparing the mean level of concern between students who measured high on the religious belief scales with those who measured low on the religious belief scale.

#### **4.10.1 Analysis of Affective Concerns**

To further explore the role of religious belief on students' levels of concern about specific technologies, an independent *t*-test was performed with low and high level of Christian religious belief being the grouping variable and the eight

biotechnologies being the test variables. The categorisation of students into low or high levels of Christian religious belief has been previously described in Section 4.6. Effect sizes were also calculated as recommended by Cohen (1988) so that an estimate could be made of the magnitude of the differences, allowing for a comparison to be made between students with low level of religious belief and those with high level of religious belief. Because the sample size was different for each group, the effect size was calculated using Hedge's  $g$ , which provides a more conservative estimate of effect size than Cohen's  $d$  (Coe, 2002).

The results of this analysis are shown in Table 4.10, where the biotechnologies appear in order from least to most concern as ranked by all participating students. Because a more positive attitude towards biotechnology was coded throughout the questionnaire as having a higher value, the eight concerns about biotechnology were all reverse coded so that a higher score corresponds to the student being less concerned about the technology, while a low score indicates that they are very concerned. A score of three is indicative of a neutral response. Both groups of students ranked their concerns similarly, the only exception being that students with a low level of religious belief placed Animal Cloning as being of more concern than Therapeutic Human Cloning. These results are shown graphically in Figure 4.1, where the graph is based on the item mean scores for each of the technologies.

#### **4.10.2 Analysis of Ethical Dilemmas**

The students' level of agreement with the ethical dilemmas presented in the BARBQqual were also analysed to compare differences between students with a high level of religious belief and those with low level of religious belief. An independent  $t$ -test was performed with level of religious belief being the grouping variable and the four biotechnology dilemmas being the test variables. Effect sizes were also calculated so that an estimate could be made of the magnitude of the differences between students with low levels of religious belief and those students with high levels of religious belief. The results of this analysis are shown in Table 4.10, where the ethical dilemmas appear in the order of mostly agree to disagree with the technology. For consistency, a positive attitude towards biotechnology was coded throughout the questionnaire as having a higher value, and therefore a higher score on the dilemmas represents a greater agreement with the use of the technology. A neutral response was scored as a three. These results are shown graphically in Figure

4.1, where the graph is based on the item mean scores for each of the dilemmas.

#### **4.10.3 Summary of Students' Concerns About Biotechnology**

Of the 12 items examining the use of biotechnology, 10 showed statistically significant differences between the students who scored high on the Christian Worldview Scale (CWS) and were therefore classified as having a high level of religious belief, and those students that scored low on the CWS and were consequently classified as having a low level of religious belief. Students' concerns about Animal Cloning, Reproductive Cloning, Genetically Modified Food, Therapeutic Cloning and Pre-implantation Genetic Screening showed statistical significant differences ( $p < 0.001$ ) between students with a high level of religious belief and those with a low level of religious belief. Genetic Modification of Plants, Genetic Modification of Animals, Genetic Modification of Humans and Reproductive Cloning had statistically significant differences at  $p < 0.01$  and IVF had statistically significant differences at  $p < 0.05$ . Two of the twelve technologies, Genetic Modification of Bacteria and Therapeutic Human Cloning, did not have statistically significant differences between the students with low levels of religious belief and those with high levels of religious belief. For each of the technologies investigated the students with a high level of Christian religious belief were, on average, more concerned than their peers who were grouped as having a low level of religious belief.

Students who recorded a low level of religious belief also scored below neutral in that they indicated, on average, that they were moderately concerned or very concerned about four of the ten items with statistically significant differences between the high and low levels of religious belief. These consisted of the two reproductive cloning items, one from the affective concerns strand of the *BARBQquant* and the other from the biotechnology ethical dilemmas section of the *BARBQqual*, as well as 'genetic screening' and 'genetic modification of humans'. In contrast, those students with a high level of religious belief indicated, on average, that they were moderately concerned or very concerned about seven of the ten technologies with statistically significant differences, Animal Cloning, Genetic Modification of Animals, Genetic Modification of Humans, Reproductive Human Cloning, Dilemma Genetic Screening, Dilemma, and Dilemma Reproductive Cloning.

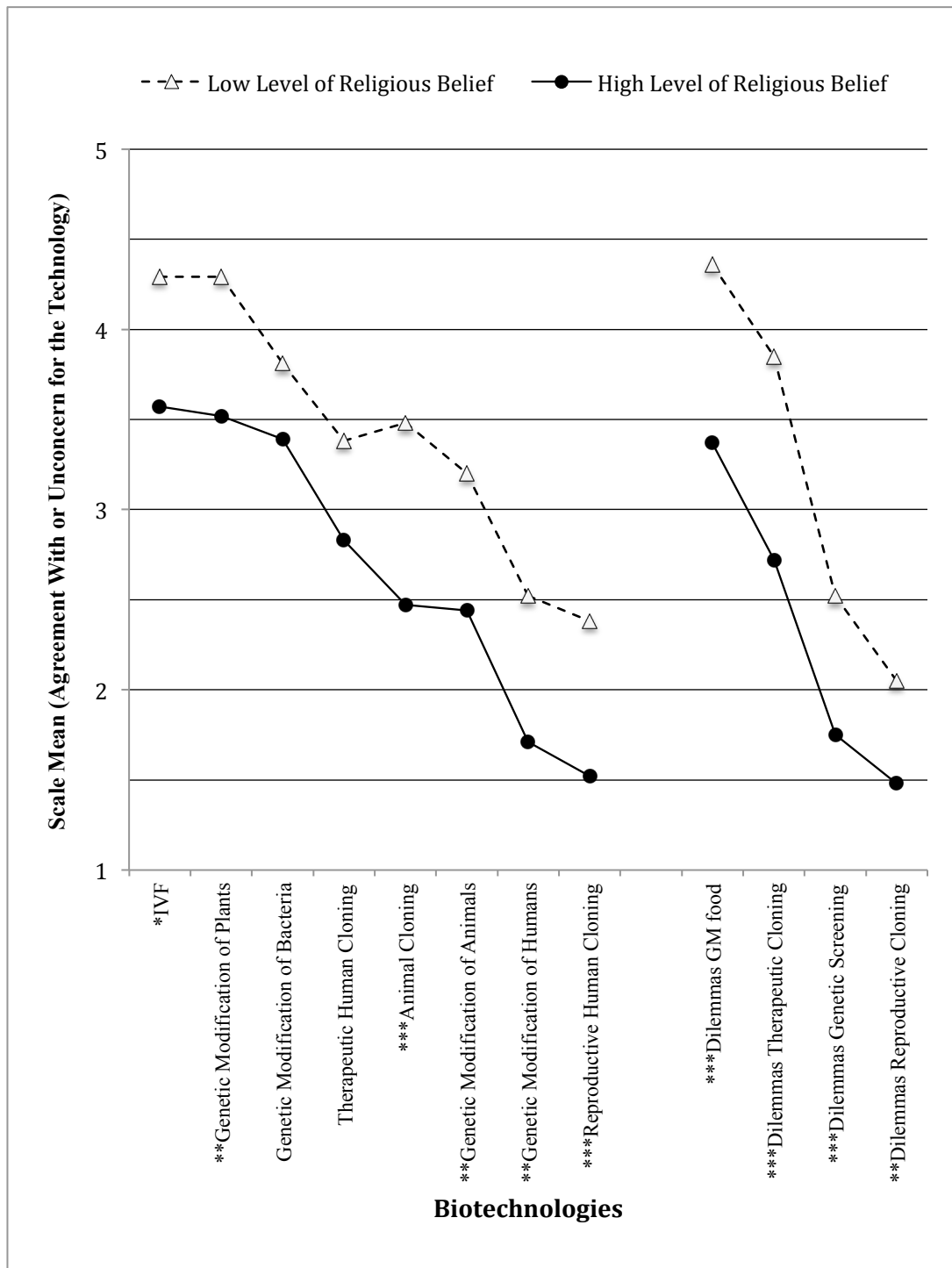
Table 4.10 *Differences Between Low and High Levels of Religious Belief for Concerns About Biotechnology Showing Item Mean, Standard Deviation, t-Test and Effect Size*

Scale	Item Mean		Item SD		Difference	
	Low	High	Low	High	Effect Size <sup>a</sup>	<i>t</i>
IVF	4.29	3.57	1.31	1.28	0.56	2.35*
Genetic Modification of Plants	4.29	3.52	1.10	1.33	0.59	2.50**
Genetic Modification of Bacteria	3.81	3.39	1.25	1.25	0.33	1.4
Therapeutic Human Cloning	3.38	2.83	1.65	1.51	0.35	1.52
Animal Cloning	3.48	2.47	1.50	1.33	0.74	3.11***
Genetic Modification of Animals	3.20	2.44	1.43	1.21	0.61	2.53**
Genetic Modification of Humans	2.52	1.71	1.47	1.05	0.72	3.06**
Reproductive Human Cloning	2.38	1.52	1.56	1.01	0.77	3.26***
<b>Ethical dilemmas</b>						
GM Food	4.36	3.37	0.91	1.14	0.89	3.71***
Therapeutic Cloning	3.85	2.72	1.33	1.45	0.75	3.16***
Genetic Screening	2.52	1.75	0.98	0.87	0.86	3.58***
Reproductive Cloning	2.05	1.48	1.08	0.90	0.61	2.50**

Note. Low = Low Level of Religious Belief ( $n = 21$ ); High = High Level of Religious Belief ( $n = 117$ ). High mean corresponds to low level of concern; Low mean corresponds to a high level of concern

<sup>a</sup> Hedge's  $g$ .

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$



Note. A high mean represents a decreased level concern about biotechnology, 1 = very concerned or disagree, 3 = neutral or unsure, 5 = unconcerned or agree.

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$

Figure 4.1 *Differences in concerns about biotechnology for students with low and high levels of religious beliefs.*



The three technologies on which the high level of religious belief students and the low level of religious belief students did not agree in regard to supporting or not supporting the technology were: Therapeutic Human Cloning, Animal Cloning, and Genetic Modification of Animals. To understand why this difference of opinion exists, the additional information collected to address research question three is required, and is discussed in Chapter 8.

#### **4.10.4 Key Findings of Students' Concerns About Biotechnology**

For all of the technologies presented in this study, students with a high level of religious belief generally had a greater concern about the technology or disagreed more with its use than those students with a low level of religious belief. Student concerns about biotechnology increased as the technologies moved from the modification of plants and bacteria through to the modification and cloning of animals, with the most concern being shown for genetic modification of humans and reproductive cloning of humans. The application of biotechnologies that involve Therapeutic Human Cloning, Animal Cloning, and Genetic Modification of Animals is an issue on which student opinion is divided so that students with a low level of religious belief are, on average, more willing to support or are not concerned about the technology, while students with a high level of religious belief are, on average, more unwilling to support or are more concerned about the use of the technology.

#### **4.11 SUMMARY OF CHAPTER AND KEY FINDINGS**

The purpose of this chapter was to report on the statistical analyses used to validate the BARBQ as well as the results from the analyses of the data collected from the sample that addressed the first research question: How does religious belief act as a predictor of attitudes towards biotechnology?

Before directly addressing the first research question, this chapter reported data preparation, demographic data for the sample, and the statistics used to test the validity of the BARBQ. The results presented in this chapter justified the use of the BARBQ, which has good internal consistency, reliability and discriminant validity, and is therefore an appropriate instrument to measure students' attitudes towards biotechnology and their Christian religious belief for the purpose of this study. This chapter showed that, for both male and female students, a higher level of religious belief is associated with a decrease in student attitudes towards biotechnology. Using

correlation and regression analyses, it was shown that Christian Orthodoxy, Biblical Literalism and Religiosity all provide predictive power for determining students' general attitudes towards biotechnology; the extent to which students agreed with the applications of biotechnologies involving Genetically Modified Food, Pre-implantation Genetic Screening, Therapeutic Cloning, and Reproductive Cloning was also determined.

In the analysis of student concerns about the application of biotechnology, this chapter provided evidence from *t*-tests that students with a high level of religious belief are more concerned about applications of biotechnology than their less religious peers. It also confirmed the trend observed by other researchers that highlighted an increased level of concern amongst students regarding biotechnology issues involving animals and humans as opposed to applications of biotechnology involving bacteria or plants.

The next chapter of this thesis addresses Research Question 2 involving the analysis of students' informal reasoning. It presents quantitative data in the form of descriptive statistics to identify if students with a high level of religious belief use different patterns of informal reasoning from students who scored lower on the Christian Worldview Scale (CWS).

## **Chapter 5**

### **RESULTS AND ANALYSIS OF RESEARCH QUESTION 2**

#### **5.1 INTRODUCTION**

Chapter 5 presents an analysis of the data that addresses the second research question, which was to determine if the acceptance of Christian religious beliefs, a Christian Worldview, affects students' patterns of informal reasoning. To answer this question, student responses to the four biotechnology ethical dilemmas were analysed for patterns of informal reasoning.

After the introduction, the section 5.2 describes the analysis of patterns of informal reasoning and includes a description of the terms, coding and procedures used in the analysis of students' responses. Through the use of student quotes, Section 5.3 of this chapter describes the criteria that were used to identify rational, intuitive, and emotive informal reasoning. Section 5.4 describes the analysis of patterns of informal reasoning through the frequency of the three modes, rational, intuitive, and emotive. Comparisons with previous research are made and the key findings of this section are highlighted. Section 5.5 then compares the pattern of informal reasoning used by students with a low level of religious belief with those students who were identified as having a high level of religious belief. Summaries of the analysis and key findings are also presented for this section. The final section 5.6 provides a summary of the chapter and its key findings.

#### **5.2 ANALYSIS OF INFORMAL REASONING**

Informal reasoning was described in Section 2.4.1 as: the reasoning performed by an individual as they assess multiple lines of evidence that do not point to an obvious solution. It has been suggested by Sadler and Zeidler (2005a) that informal reasoning can be categorised according to whether a comment utilises a logical and systematic process, referred to as rational informal reasoning, or rather, if a comment is based on an emotional response, referred to as affective informal reasoning, or finally, whether a comment is one of intuitive informal reasoning that is based on a gut feeling. Sadler and Zeidler (2005a) noted that students would often use more than one type of informal reasoning when approaching ethical issues. An argument was presented in the literature review (Section 2.4) that an analysis of students' patterns of informal reasoning may be useful in exploring the differences and similarities

between the thinking of students with a low level of religious belief and those with a high level of religious belief.

In the final section of the BARBQ, students were asked to state whether they agreed or disagreed with the use of four separate biotechnologies and to list the reasons why they either agreed or disagreed with the use of the biotechnology. The four applications of biotechnology, presented as ethical dilemmas, were used to explore the students' thinking about Genetically Modified Food (GM Food), Pre-implantation Genetic Screening (PGS), Therapeutic Cloning (T. Clone), and Reproductive Cloning (R. Clone). A complete description of each question is found in the questionnaire utilised in this study, the BARBQ, and presented in Appendix A. Each of these questions is associated with complex social and scientific issues and none have simple answers that can be approached in a purely deductive manner. Instead, these four ethical dilemmas require students to utilise informal reasoning as they come to a decision about their personal stance on each of these socioscientific issues.

### **5.2.1 Description of Terms and Coding for Patterns of Informal Reasoning**

For the purpose of this study, specific language has been employed in making reference to the written answers made by the students. A 'statement' refers to one sentence or phrase made by the student; for this study, a statement is not a student's full response to an ethical dilemma but rather represents the unit that was identified and coded as rational, emotive, or intuitive. A 'comment' refers to a student's complete answer to one ethical dilemma. In this way, the frequency of rational informal reasoning in the total comments would be the sum of all comments that included a statement that was coded as rational. The term 'response' is used to describe all of the written material made by a student in the *BARBQqual*. Using this terminology, the frequency of intuitive reasoning in total responses would refer to the number of students who used intuitive reasoning in one or more of the ethical dilemmas. Because some students did not complete all sections of the *BARBQqual*, the students' response may include only one comment or up to four comments. Students who did not provide any written answers to the *BARBQqual* were not included in the sample.

A total of 147 out of 177 students responded to at least one of the ethical dilemmas. This results in a possible 588 comments; however, as some students did not answer all of the ethical dilemmas, there were only 504 comments that could be analysed. The statements in each ethical dilemma were read through in full, before a second reading, which was used to determine the mode of informal reasoning used in the comments. Any statements that could not be easily categorised were marked for review. The coded responses were read through a third time, once all statements had been coded, to check for consistency in the coding. Vaille Dawson, one the co-authors of a study investigating high school students' informal reasoning about biotechnology (Dawson & Venville, 2009), and therefore familiar with Sadler and Zeidler's (2005a) patterns of informal reasoning, reviewed the coding of the students' comments. No significant discrepancies were found between the two researchers' codification of the statements, with any minor differences being resolved upon discussion. Table 5.1 summarises the three modes of informal reasoning, along with an example from the questionnaire transcripts.

Table 5.1 *Description and Exemplars for Each Mode of Informal Reasoning*

<b>Informal Reasoning</b>	<b>Description<sup>a</sup></b>	<b>Examples</b>
Rational	“Logical, uses scientific understanding and language, weighs up risks and benefits, advantages and disadvantages”	The over-reliance on insecticides nowadays will increase the insects' resistance and cause future repercussions, as well as allowing chemical corporates [sic] to take more money out of hard-working farmers for fertilisers/chemicals. (167)
Emotive	“Emotional response towards stakeholders, care, empathy, sympathy, concern for the plight of those affected”	Parents would be glad to have a child. But the child might think differently if it knew that he/she was born not from their parents but their clones. (154)
Intuitive	“Gut feeling, immediate response, strongly held, often a negative response, personal, often precedes rational or emotive”	I wouldn't do it still because it [cloning] is wrong. (175)

Note. <sup>a</sup>From Dawson and Venville (2009, p. 1431)

### 5.3 MODES OF INFORMAL REASONING

This section uses the statements written by students to provide an in-depth description of how statements were coded as rational, emotive, or intuitive; this was done to ensure a clear understanding of what the three modes of informal reasoning represent. Student comments are labelled with a 'R', 'E' or 'I' to identify the mode of informal reasoning used, along with the identification code for that student.

Because individual statements within a comment were coded, a student's comment to a single question may have contained one, two or all three of the modes of informal reasoning. For example, in answering the ethical dilemma on GM food, one student utilised only rational informal reasoning.

Genetically modified food has a longer lasting shelf life and could feed many hungry people. (*R, 112*)

Some students utilised two or more modes of reasoning when responding to an ethical dilemma. The following comment provides an example that shows the inclusion of both rational and emotive informal reasoning.

GM foods such as rice can help many third world countries in their battle against illness. Ignoring another person's desperate needs just because we are not comfortable with it is very self-centred way of thinking. (*R, E, 344*)

In the above example, the first sentence was coded as rational while the second sentence was coded as emotive. For the purpose of analysis, every different mode of informal reasoning within a comment was counted as a separate statement. This approach allowed for the variety of students' patterns of informal reasoning to be accounted for, and remains consistent with the approach taken by Sadler and Zeidler (2005a) and Dawson and Venville (2009), who describe the use of multiple modes of reasoning in student responses to socioscientific issues.

#### 5.3.1 Rationalistic Informal Reasoning

Statements that used rational informal reasoning were identified using the criteria adopted by Dawson and Venville (2009, p. 1431), which described rational statements as "Logical, uses scientific understanding and language, weighs up risks and benefits, advantages and disadvantages".

Statements coded as rational informal reasoning often incorporated scientific knowledge and weighed up risks and benefits. The following statements demonstrate the use of scientific knowledge and language used by students when undertaking

rational informal reasoning.

The over-reliance on insecticides nowadays will increase the insects' resistance and cause future repercussions, as well as allowing chemical corporates [sic] to take more money out of hard-working farmers for fertilisers/chemicals. (R, 167)

But [cloning] could be bad because the life expectancy of the child will decrease as the donor is pretty old so its mum is old too. Example of Dolly the sheep as she was cloned from a 6 year old sheep she had DNA aged 6 and she died at the age of 6, life expectancy for sheep is 12. (R, 415)

It can help third world countries and it helps keep food prices down but it also is a considerable danger to the future of agriculture. It restricts biodiversity and could have an effect on our wildlife that could be devastating. (R, 155)

Every student incorporated rational reasoning in providing scientific reasons to support their views about genetically modified food. Student 167 clearly stated what he considered to be the benefits of the technology, while student 415 has identified risks in using very specific scientific knowledge. Student 155 identified both risks and benefits.

Even though they did not include scientific evidence, some students provided a detailed response and attempted to weigh up the risks and benefits; these statements were also coded as rational.

[Pre-implantation genetic screening] may be beneficial to find any genetic diseases, but in my opinion we should not alter the future baby's physical characteristics. If people modified their future children, the standard of society will be elevated and other people who are not modified have to 'step-up' in order to fit in the society. (R, 151)

Other statements, also classified as rational, provided a simple but logical explanation of the advantages of the technology, as demonstrated by this individual's response to genetic screening: "Getting rid of the diseases before birth may save the child's life". (R, 161)

### **5.3.2 Intuitive Reasoning**

Intuitive statements were also identified using the description outlined by Dawson and Venville (2009, p. 1431), who described intuitive reasoning as "Gut feeling, immediate response, strongly held, often a negative response, personal, often precedes rational or emotive".

Many students expressed a short statement that appeared to be a ‘gut response’, one that offered no explanation or logical analysis of the situation. Such statements included “This makes me sick” (I, 337), “Let what happens happen” (I, 333) and many statements that included the phrase ‘playing God’.

Many of the students had strongly-held beliefs about these issues and this was clearly evident in the intuitive statements they made. The following examples provide evidence of this.

The chances that cloning would be successful are slim and playing with human life is crossing the line. Have we finished stuffing up everything that we just decide that it’s OK to play with human life. (I, 409)

NO!! This is ethically wrong. ... This would mean a mini parent would be born. The purpose of this is to serve people’s ‘selfish’ motives of having a baby. There are many, many, many, many orphans who need parents – adopt a child instead of creating one. (I, 314)

The personal nature of the responses was also evident, with some students recognising that this was a personal view that need not be enforced upon others.

I think that all parents should have the choice about there [sic] children. I’m not sure if I would change my children but I think that others should have the choice. (I, 311)

As sad as it is that some woman [sic] can’t have children & want to clone, I kinda agree. If I was in that situation however, I wouldn’t do it still because it [cloning] is [morally] wrong. (E, I, 175)

Although not always the case, intuitive reasoning was often accompanied by a rational and/or emotive statement, which attempted to provide support for, or exemptions to, an initial intuitive response. The following two responses provide examples of this. In the first example provided below (319), an initial intuitive statement is followed by a rational statement that supports the intuitive response. The second example shows an emotive statement that qualifies the initial intuitive statement.

Children are a gift and a surprise not something you order. May ruin the male / female balance, ending up with more of one than the other. (I, R, 319)

We shouldn’t deal with those things [GM food] because it’s not right. On the other hand, it could help farmers and people living in poverty. (I, E, 175)



### 5.3.3 Emotive Reasoning

Dawson and Venville (2009, p. 1431) provide a description of emotive reasoning and this was used as a guide in determining which statements would be classified as emotive reasoning. These authors described emotive reasoning as “emotional response towards stakeholders, care, empathy, sympathy, concern for the plight of those affected”. Emotive reasoning represented the least-used mode of informal reasoning; however, a number of statements were identified that conformed to the above description.

The identification of the stakeholders was a key component in determining emotive reasoning. The following response is an example of a student who explicitly identified a number of the stakeholders and provided an emotive response to their situation.

*Parents* would be glad to have a child. But the *child* might think differently if it knew that he/she was born not from their parents but their clones. [emphasis mine] (E, 154)

The next two statements show that concern, sympathy and empathy were incorporated into the resolution of these ethical scenarios.

It is painful for parents to live with a diseased child. (E, 167)

It's good to give couples a chance to reproduce. (E, 166)

This student focused on our need to care for people in general.

We should always be looking for ways to help people. (E, 331)

The need to care for the poor in developing countries was a common statement made in response to the genetically modified food issue, one typical example being:

If it is going to help people in third world countries from hunger then yes it is good. (E, 414)

While disagreeing with the use of the technology, some students were still able to show sympathy to those facing these difficult decisions, as this student showed when responding to the dilemma on reproductive cloning.

Being unable to ... have a child would be heartbreaking but I still believe that cloning is wrong. (E, I, 305)

Other students demonstrated empathy by identifying with the emotions of others.

If there is the possibility that diseases could be reduced in the child, what mother or father wouldn't want to have the peace of mind that they are having a healthy child. (E, 315)

This will make couples extremely happy to be able to have their own child. (E, 413)

#### **5.3.4 Summary of Description and Coding of Informal Reasoning**

This section has provided a rich description of students' rational, intuitive and emotional reasoning and demonstrated how students' statements were coded so that a clear understanding of the meaning of these terms within the context of this study could be obtained. The next section provides data about how often each mode of informal reasoning was used by students.

### **5.4 PATTERNS OF INFORMAL REASONING**

While coding the informal reasoning of students, it was observed that, consistent with other studies (Sadler & Zeidler, 2005a; Topçu et al., 2010; Yap, 2012), students were using some modes of reasoning more often than other modes. The frequencies with which students use informal reasoning and the manner in which those modes are combined are referred to as the patterns of informal reasoning. This study uses the term in a narrower sense to describe only the frequency with which the three modes of informal reasoning are used when responding to ethical dilemmas.

#### **5.4.1 Analysis and Comparison of Patterns of Informal Reasoning**

The frequency for each of the modes of informal reasoning was tallied and the results are presented in Table 5.2, which also shows the percentage for rational, emotive and intuitive informal reasoning as well as for those students who did not respond. The total percentage of comments and the total percentage of student responses are also shown.

To compare these results with those of other studies discussed in Section 2.4.3 that have also measured students' patterns of informal reasoning, simplified ratios of rational, emotive and intuitive reasoning were calculated. These ratios, along with the ratios reported in previous studies, are presented in Table 5.3.

#### **5.4.2 Summary of Patterns of Informal Reasoning**

As shown in Table 5.2, the frequency of the modes of informal reasoning varied across the different dilemmas. In the first question, which explored students' attitude towards genetically modified food crops, students relied heavily on rationalistic reasoning. The intuitive mode of informal reasoning was the larger contributor in the remaining three dilemmas of Pre-implantation Genetic Screening, Reproductive

Cloning and Therapeutic Cloning. The frequency of emotive reasoning was low across all of the dilemmas. This is in agreement with other studies, which have shown that patterns of informal reasoning will change depending on the context of the issue (Dawson & Venville, 2009; Sadler & Zeidler, 2005a; Topçu et al., 2011; Yap, 2012). The percentage of non-responders increased as the students progressed through the ethical dilemmas in the questionnaire, GM Food was the first ethical dilemma, and Therapeutic Human Cloning the last; the likely cause is that students were experiencing survey fatigue.

Table 5.2 *Percentage of Students Using Each Mode of Informal Reasoning*

Informal Reasoning	GM Food	PGS	R. Clone	T. Clone	Total (Responses)	Total (Comments)
Rational	69	37	16	33	77	45
Emotive	14	12	15	10	35	15
Intuitive	37	68	61	40	87	60
No Response	5	8	18	26	0	14
Students n = 147, Comments n = 588						

Note. GM Food = Genetically Modified Food; PGS = Pre-implantation Genetic Screening; R. Clone = Reproductive Human Cloning; T. Clone = Therapeutic Human Cloning.

The total student responses indicate that 77% of students used rational reasoning in at least one ethical dilemma. This number is higher for intuitive reasoning, which has 87% of students using that mode in at least one comment. Only 35% of students used emotive reasoning in their response. When the total responses are compared to the total comments and the individual ethical dilemmas it is evident that intuitive reasoning, rather than the rational or emotive modes of reasoning, is used much more frequently by students when negotiating these socioscientific issues.

The patterns of informal reasoning of students in this study is comparable to the patterns of informal reasoning found by Yap (2012) who, like this study, also researched Australian high school students in a Christian faith-based school. Although her study involved younger students, Year 10 as opposed to Year 11 and Year 12 students, the two studies both used the same ethical dilemmas. Students in

the research performed by Dawson and Venville (2009) incorporated on average more emotive reasoning; however, their study utilised a different set of ethical dilemmas. Despite the current study and Yap's (2012) research both using the same ethical dilemmas as Sadler and Zeidler (2005a), the ratio of informal reasoning identified by Sadler and Zeidler (2005a) amongst American university-level students was very different from that found in the studies involving Australian high school students, who typically used less rational reasoning and more intuitive reasoning. Similar to the American study involving university students, an increased use of rational informal reasoning was evident in the research by Topçu et al. (2011), which identified rational reasoning as the most frequently used mode of informal reasoning amongst Turkish university students. Emotive reasoning was the least utilised mode of informal reasoning for all but the study by Sadler and Zeidler (2005a).

Table 5.3 *Patterns of Informal Reasoning*

Study	Rational	Emotive	Intuitive
<i>Current study (total comments)</i>	3	1	4
Sadler & Zeidler, (2005a, 2005b)	2	1	0.5
Dawson & Venville, (2009)	1	1	1
Topçu et al., (2011)	3	1	1
Yap, (2012)	3	1	5

### 5.4.3 Key Findings for Patterns of Informal Reasoning

Section 5.4 has compared the informal reasoning of students in this study with the patterns of informal reasoning found in earlier research. The results presented here confirm previous research in that a student's informal reasoning changes depending on the ethical dilemma to which the student is responding. This section has also shown that the informal reasoning of students in this study is comparable to that of other studies from a similar cultural and educational context (i.e. Australian high school students attending a Christian coeducational school).

## 5.5 INFORMAL REASONING AND RELIGIOUS BELIEF

The previous section provided an overview of students' patterns of informal reasoning and compared it to the informal reasoning of students in earlier research.

This section examines how students' religious belief affects the patterns of informal reasoning used by students.

### **5.5.1 Analysis of Informal Reasoning and Religious Belief**

To examine how the acceptance of a Christian religious belief may affect students' patterns of informal reasoning, the percentage of students who used rational, emotive and intuitive reasoning in their comments and responses was calculated for the students who scored high on the Christian Worldview Scale (CWS), and those students who scored low on the same scale. The grouping of the sample into students who had a high level of religious belief and those with a low level of religious belief has been previously described in Section 4.6. As was explained in that section, those students who scored midway on the CWS were removed from the sample. While this provided a clearer distinction between students with a high and low Christian religious belief, it resulted in a decreased sample size. Therefore, for the analysis of informal reasoning and students' Christian worldview, the total sample is 122 students consisting of 21 with a low level of religious belief and 101 with a high level of religious belief. The total number of comments provided by the 122 students is 423, which includes 75 comments from students with a low level of religious belief and 348 comments from students with a high level of religious belief. As described in Section 5.3 the use of one mode of reasoning, such as rationalistic reasoning, could be, and often was, accompanied by another mode of reasoning such as emotive and/or intuitive. Because of the non-independence between the modes of reasoning, it was considered inappropriate to compute inferential statistics to determine differences. Instead, the percentage of students who employed each mode of reasoning at least once, separated according to whether the student scored high or low on the CWS, is presented in Table 5.4 for each of the four dilemmas.

### **5.5.2 Summary of Informal Reasoning and Religious Belief**

In comparing the informal reasoning of the high and low levels of religious belief groups, some small but consistent trends were observed. Students who scored high on the Christian Worldview Scale (CWS) employed rationalistic and emotive reasoning less often than those with a low level of religious belief, and they used intuitive reasoning more frequently than the students who scored low on the CWS. For all but the GM food ethical dilemma, the pattern of informal reasoning was similar for both the high and low believers, with intuitive reasoning being the most

used, followed by rational reasoning, with emotive reasoning used the least. The GM food dilemma differed in that for this issue only, students used rational reasoning more frequently than the other two modes. As well as this difference, students with a low level of religious belief used emotive reasoning more often than intuitive reasoning.

As observed in Table 5.4, for each of the four ethical dilemmas, students with a high level of religious belief used less rational reasoning than their less religious peers. The percentage of students with high level of religious belief who used rational reasoning at least once in their response was 76%, which is far fewer students than the low level of religious belief sample, which had 95% of students using rational reasoning.

Students with a high level of religious belief used less emotive reasoning than either the rational or intuitive modes for each of the dilemmas, when compared to students with a low level of religious belief. Fewer students with a high level of religious belief utilised the emotive mode of informal reasoning in their response, as shown by the total responses in Table 5.4. Highly religious students who did use emotive reasoning did so less often than their less religious peers, as is indicated by the total comments in Table 5.4.

Students with a high level of religious belief used more intuitive informal reasoning for three of the ethical dilemmas; Genetically Modified Food (GM food), Pre-implantation Genetic Screening (PGS) and Reproductive Human Cloning (R. Clone). In the Therapeutic Human Cloning dilemma (T. Clone), students with a high level of religious belief used intuitive reasoning less often than those students with a low level of religious belief. The relationship between a high level of religious belief and the increased use of intuitive reasoning is more obvious when the number of responses that utilised each mode of reasoning is considered. Most of the students with a high level of religious belief (91%) used intuitive reasoning at least once in their response, while only 76% of students with a low level of religious belief used intuitive reasoning. Table 5.4 also shows that the total number of intuitive comments made by students scoring high on the CWS is greater than those students who scored low on that scale, which indicates that not only do more students use intuitive

reasoning if they have a high level of religious belief, but they also use intuitive reasoning more frequently than their less religious peers.

### **5.5.3 Key Findings for Informal Reasoning and Religious Belief**

This section has provided evidence that suggests that students with a high level of religious belief use more intuitive reasoning, and consequentially less rational and emotive reasoning, than students with low level of religious belief. Caution needs to be taken in coming to any conclusion regarding these data because of the small sample size in this study. These results suggest that students with varying levels of religious belief may employ rationalistic, emotive, or intuitive informal reasoning differently when considering socioscientific issues. More specifically, the data suggest that students identified as having a Christian worldview utilised more intuitive reasoning and less rational and emotive informal reasoning. Additional research, incorporating a larger sample size, is required to confirm these findings.

Table 5.4 *Percentage of Comments and Responses Utilising Each Mode of Informal Reasoning for High and Low Religious Belief*

Informal Reasoning	GM Food		PGS		R. Clone		T. Clone		Total (Responses)		Total (Comments)	
	Low <sup>a</sup>	High <sup>b</sup>	Low <sup>a</sup>	High <sup>b</sup>	Low <sup>a</sup>	High <sup>b</sup>	Low <sup>a</sup>	High <sup>b</sup>	Low <sup>a</sup>	High <sup>b</sup>	Low <sup>c</sup>	High <sup>d</sup>
Rational	81	70	38	37	33	15	38	33	95	76	53	45
Emotive	19	14	14	9	24	15	14	7	43	34	20	13
Intuitive	14	42	52	73	52	63	43	39	76	91	45	63
No Response	5	3	14	7	10	18	14	26	-	-	12	16

Note. GM Food = Genetically Modified Food; PGS = Pre-implantation Genetic Screening; R. Clone = Reproductive Human Cloning; T. Clone = Therapeutic Human Cloning.

<sup>a</sup> From the sample of Low Christian religious belief,  $n = 21$  students / responses. <sup>b</sup> From the sample of High Christian religious belief,  $n = 101$  students / responses. <sup>c</sup> From the sample of Low Christian religious belief,  $n = 75$  comments. <sup>d</sup> From the sample of High Christian religious belief,  $n = 348$  comments.



## 5.6 SUMMARY OF CHAPTER AND KEY FINDINGS

This chapter has presented data that can be used to answer the second research question: How does student's Christian religious belief affect their patterns of informal reasoning? The first section provided a detailed description of the rational, emotive and intuitive reasoning used by the cohort of students in their study, so that the informal reasoning described here could be placed within the context of other studies found in the literature. An attempt was made to provide a comparison between the results found in this study and those of previous research identifying patterns of informal reasoning. It was shown that this cohort used patterns of informal reasoning that were comparable to those from in other studies involving Australian secondary students, including a variation in the patterns of informal reasoning, depending on the issue that was being addressed.

The results presented here provided initial evidence for a difference in the patterns of informal reasoning used by students with a high level of religious belief, when compared against students with a low level of religious belief. The research presented here represents some of the first data to suggest that secondary students with a Christian worldview use more intuitive reasoning and less emotive and rational reasoning than their peers who do not identify with a Christian worldview. In presenting these data, the limitations of the research, and the need for more research in this field, were identified.

The next chapter presents the findings relevant to the third research question, which sought to determine how students' religious beliefs are incorporated into their informal reasoning about biotechnology. This is achieved by presenting the ethical arguments that were identified in the student responses to four ethical dilemmas about genetically modified food, therapeutic cloning, reproductive cloning, and pre-embryotic genetic testing, as well as the data obtained from the semi-structured interviews.

## **Chapter 6**

### **RESULTS AND ANALYSES FOR RESEARCH QUESTION 3**

#### **6.1 INTRODUCTION**

In this chapter, the results and analysis of the third research question are addressed. The third research question asked: How are students' religious beliefs incorporated into their informal reasoning about biotechnology? This question will be addressed through a presentation of the qualitative data obtained from the students' extended responses to the qualitative section of the Biotechnology Attitudes and Religious Belief Questionnaire (BARBQ*qual*), and a description of the ethical arguments used by students when they were reasoning about biotechnology issues. The research question will also be addressed through the presentation of statistical analysis carried out on the ethical arguments identified during the qualitative analysis, and by describing the level and frequency with which students incorporated their religious beliefs into their informal reasoning about biotechnology.

Following the introduction, Section 6.2 provides a description of 12 ethical arguments that were identified in the students' informal reasoning and the frequency with which the students raised these ethical arguments. Section 6.3 presents an analysis of data used to examine the differences in attitudes towards biotechnology of students who assimilated the ethical arguments into their response, and those who did not. Section 6.4 provides a similar analysis, but compares students' level of religious belief, instead of their attitudes towards biotechnology. Section 6.5 describes the development of the Reasoned Religious Belief Level (RRBL), and the results of an analysis of the frequency with which students used each level of the RRBL. The final section (Section 6.6) provides a summary of the results and key findings presented in this chapter.

#### **6.2 ETHICAL ARGUMENTS IN STUDENTS' REASONING**

As described in Chapter 1, the third research question involved how students' religious beliefs were explicitly incorporated into their informal reasoning about biotechnology. This section describes the ethical arguments utilised by students when responding to the different biotechnology dilemmas presented in the questionnaire and the semi-structured interviews. The questionnaire presented

students with four ethical dilemmas dealing with genetically modified plants, pre-implantation genetic screening, therapeutic cloning and reproductive cloning. Students were asked to write comments about why they thought that the technologies were acceptable or not. With 147 students responding to at least one of the ethical dilemmas, the questionnaire provided a rich source of data with which to explore the use of ethical arguments in students' responses. Quotes from students' responses to the questionnaire have been referenced using the identification number assigned to each student by the researcher. The interviews provided a means of further elucidating students' thinking about these issues and providing clarity to the descriptions of the ethical arguments that were identified. The interviews presented a range of biotechnologies to the students involved and revisited the issues of genetically modified organisms, therapeutic cloning, and reproductive cloning with a greater range of examples using plants, animals and humans. Students were encouraged to explore their ethical reasoning and asked to provide reasons for their views. Quotes that originated from the semi-structured interviews are identified by a name, which has been changed from the student's actual name, but which is consistent with the gender of the student.

### **6.2.1 Ethical Arguments Used by Students**

In Section 2.6 of this thesis, the religious arguments concerning biotechnology were reviewed and five arguments were identified that are often addressed by religious groups when discussing their opposition to biotechnology: the moral state of a human embryo, playing God, slippery slope, God is Creator, and God's will. The literature review also identified that religious institutions often express conditional support for advances in biotechnology, largely because of the health benefits resulting from the innovations offered by biotechnology to relieve suffering and increase food production. This support was tempered with issues regarding justice in the distribution of risks and benefits and the intrinsic value of human life. This suggested three additional ethical arguments that could be identifiable in the students' responses to the ethical dilemmas: health benefits, justice in the distribution of risk, and the uniqueness of individuals resulting from the intrinsic value of human life.

Using these arguments identified in the literature review as a guide, the students' comments from the questionnaire and the semi-structured interviews were re-examined to determine if the arguments identified in the literature could also be

identified amongst the students' reasoning about biotechnology. After reviewing the data, the ethical arguments involving justice in the distribution of risk were generalised to include other social justice arguments, including arguments addressing poverty and economical imbalances, and reducing hunger and malnutrition in developing countries. All of the arguments identified in the literature were observed in the student data, along with four additional ethical arguments. The additional arguments were: health concerns with the biotechnology, the use of the phrase 'not natural' or 'unnatural' by students when rejecting a particular biotechnology, and reasoning that explicitly referred to a conflict between science and faith, either because religion was limiting the progress of science, or because science was disregarding the students' faith-based concerns. Therefore a total of 12 ethical arguments were identified in the students' reasoning:

- 1) Health benefits
- 2) Social justice
- 3) Health concerns
- 4) Not natural
- 5) Playing God
- 6) God is Creator
- 7) God's will
- 8) Human embryo
- 9) Uniqueness
- 10) Slippery slope
- 11) Religion limits science
- 12) Science disregards faith.

After identifying the 12 ethical arguments, the students' comments were again reviewed and annotated so that a nuanced understanding of these arguments could be identified. The two ethical arguments involving science and religion, 'religion limits science' and 'science disregards faith' were maintained as two separate ethical arguments to reflect the diverse ideology of these two groups, and so that meaningful data could be obtained from this ethical argument. The statistical software package PASW was used to calculate the frequency of each ethical argument for the four ethical dilemmas. Table 6.1 shows the frequency (number and percentage) of students who used the ethical arguments in the BARBQ*qual*. The total in this table

refers to the total number of students who used the ethical argument at least once in their response to the four ethical dilemmas. All percentages were calculated assuming a sample size of 147, the number of students who responded to at least one of the ethical dilemma questions. Any questions that had no response were grouped with those students who did not use the ethical argument.

Table 6.2 provides a description and an example of each ethical argument used by students. To provide the reader with a clear understanding of the nature and scope of the 12 specific ethical arguments identified in this study, a detailed description has been provided for each of the ethical arguments. Each description identifies the number of students that used the ethical argument in the questionnaire, and incorporates quotes from the questionnaire and the transcribed interviews so that the authentic voice of the students can be presented.

Table 6.1 *Frequency of Students Using Ethical Arguments for Each Dilemma*

Ethical Argument	GM Food		Screening		R. Clone		T. Clone		Total	
	f	%	f	%	f	%	f	%	f	%
Health Benefits	15	10	30	20	3	2	41	28	89	61
Social Justice	62	42	3	2	3	2	1	<1	71	48
Health Concerns	31	21	6	4	15	10	12	8	64	44
Not Natural	23	16	19	13	14	10	2	1	60	41
Playing God	5	3	29	20	14	10	6	4	54	37
God is Creator	16	11	19	13	6	4	4	3	45	31
God's Will	1	<1	12	7	11	7	5	3	29	20
Human Embryo	0	0	6	4	4	3	15	10	25	17
Uniqueness	0	0	11	7	12	8	1	<1	24	16
Slippery Slope	1	<1	1	<1	1	<1	3	2	6	4
Religion limits science	2	1	0	0	1	<1	0	0	3	2
Science disregards faith	0	0	3	2	0	0	0	0	3	2

Note.  $n = 147$  students. GM Food = Genetically Modified Food; PGS = Pre-implantation Genetic Screening; R. Clone = Reproductive Human Cloning; T. Clone = Therapeutic Human Cloning; Total = total number of students who used the ethical argument at least once; f = the frequency of students using the ethical argument. Responses left blank were grouped with those students who did not use the ethical argument.

Table 6.2 *Description and Exemplars of Ethical Arguments in Reasoning About Biotechnology*

Ethical Argument	Description	Example
Health Benefits	The biotechnology has potential health benefits.	If food can be changed so that it makes people more healthy, and is able to be grown in harsh climates, then it is a blessing and should be done. (118)
Social Justice	The biotechnology is associated with social justice issues that include poverty, access to food and nutrition, and inequality.	Also helps 3 <sup>rd</sup> world countries in need of food. (159)
Health Concerns	The biotechnology has potential health risks.	These altered foods could do more harm than good as it could have adverse effects on health and create more problems. (196)
Not Natural	Biotechnology is not natural and therefore should not be used.	Cloning, in my understanding, does not involve both parents – therefore much more ‘unnatural. (304)
Playing God	The phrase ‘playing God’ is used as an argument against the use of a particular biotechnology. Sometimes, but not always, with a religious context.	We should not play God and I think that’s final. (403)
God is Creator	God created all things so only God has the authority to change His creation, and God created everything to be as good as it could possibly be, therefore biotechnology will not be beneficial in the long term.	God created the earth not man; so it is God who should have the right to change his creation not us. He made everything the way it is for a reason. (322)

(continued)

Table 6.2 *Description and Exemplars of Ethical Arguments in Reasoning About Biotechnology (continued)*

Ethical Argument	Description	Example
God's Will	God has a plan or a purpose for every individual and the use of biotechnology undermines that plan.	Don't try & change God's will. What happens, happens for a reason. (331)
Human Embryo	The biotechnology involved the destruction of human embryos, which is in direct opposition to a belief that an embryo should be considered as a human life. Therefore destroying an embryo is equivalent to the taking of a human life.	It is creating life only to kill it. It is morally wrong. That embryo is still human. It is selfish and destructive. (155)
Uniqueness	The biotechnologies would limit the uniqueness present in individuals and this would be detrimental to society or undermine religious convictions about the importance that God places on the uniqueness of an individual.	I don't believe it is right to clone people because God made everybody different. (327)
Slippery Slope	The technology is not intrinsically wrong; however, it would lead directly to behaviour or an action that would violate faith-based principles.	Although at the moment I don't think changing plants DNA is much of a problem I am concerned that people may use it as justification to do things that would be against God. (197)
Religion Limits Science	Religious beliefs and ideologies are limiting or preventing the progress of science and its ability to provide technological solutions to the health and social problems facing modern societies.	Religion tends to get in the way it's the source of all world conflicts it incites war and prevents humanity from progressing. It is a roadblock to having a perfect society. (406)
Science Disregards Faith	Science and scientists have overstepped the ethical boundaries as defined by the commenter's religious worldview.	I disagree strongly and think the scientists have overstepped ethical bounds. (199)

### **6.2.1.1 Health Benefits**

The ethical argument that biotechnology might provide health benefits to individuals was used by 89 (61%) students as an argument for the acceptance of a particular biotechnology:

Factoring out genetic diseases would create a healthier population, as for the eye colour and intelligence, that's just vanity on the parents' part. (323)

A parent's worst fear is to have an unhealthy child and considering that there are ways to prevent this, then IVF screening should be encouraged and made widely available. (203)

Despite recognising the health benefits of the technology, some students felt that they still could not accept the technology because of their religious beliefs:

Would solve many health issues, Great for those who suffer but God created us the way he intended us to be. (329)

Other students, while still having concerns about the technology, considered the health benefits to be of greater importance than their faith-based concerns:

Genetic screening sounds relatively safe and knowing children's future health will always be relevant for all parents. So even though technically they're playing 'God', the health of their children is at stake and can be fixed. (182)

Any argument that identified how a particular technology might provide better health, such as those described above, was classified as a 'health benefits' ethical argument.

### **6.2.1.2 Social Justice**

The 'social justice' ethical argument was used by 71 (48%) students and included comments that addressed poverty or economic imbalances, reducing hunger and malnutrition in developing countries, and issues dealing with inequality amongst individuals. The majority of these comments were from the first ethical dilemma, which addressed the genetic modification of plants.

The possibilities of GM Crops being able to reduce poverty, particularly in developing countries, was the first subtheme in the social justice ethical argument, with some students demonstrating a sophisticated understanding of the issues involved:

On the other hand, it could help farmers and people living in poverty. (175)

More yield- more efficiency- better income for farmers. . . . In poor countries that rely mostly on agriculture for their economy/exports, genetically modified food can be a great help and lift them from poverty. The overreliance on insecticides nowadays will increase the insects resistance and cause future



repercussions, as well as allowing chemical corporates [sic] to take more money out of hard-working farmers for fertilizers/chemicals. (167)

The second subtheme identified was the potential for genetically modified crops to provide food and enhanced nutrition for people in developing nations:

Help fight hunger/malnutrition in 3<sup>rd</sup> world countries. (189)

Yes I think genetically modified food is fantastic for the third world hunger. This type of improvement will save many lives not just in third world countries like Africa but all around the world. (410)

The third subtheme identified within the comments classified as a social justice ethical arguments was equality, which involved issues associated with discrimination or the development of social class divisions that could result from the implementation of biotechnology. This subtheme was typically used in relation to technology directly involving human advancement, such as pre-implantation genetic screening:

It'll increase the capabilities of mankind. However, if everyone's perfect no one is. People who can't afford the technique would be sidelined and look down upon. (167)

If people do have designer babies this will create a whole new class of people with superior genes. This would have a huge negative impact on the world. (153)

Despite the social justice ethical argument being identified in the literature as an issue that was important for religious groups, the students' comments relating to social justice issues in the questionnaire and the interviews were not made in conjunction with comments about religious faith, except to counter the social justice argument:

If genetically modifying plants helps in the fight against world hunger, than I agree with it. However, plants are still God's creation and I am a little hesitant about tampering with their genetic make-up. (306)

Students using the social justice ethical argument incorporated the issues of poverty, access to food and nutrition, or equality into their arguments concerning a particular biotechnology. However, the students did not acknowledge that this was a direct result of their Christian worldview.

### **6.2.1.3 Health Concerns**

There were 64 (44%) students who used ethical arguments highlighting health concerns as a reason to reject a particular biotechnology:

It's done with good intentions but leads to the possibility of more health problems. From what I do know it just brings more negatives than positives. (407)

Some of these students were still supportive of the technology, but needed reassurance that there were no health risks associated with it:

I would definitely agree with the use of genetically modified food as long as it has been clearly tested that there are no health risks, and they also provide the same health benefits of normal crops. (327)

Others felt that the possibilities of detrimental health effects in the future, while still unknown, were too great a risk to support the technology:

I disagree because ... we don't know the long-term effects of the GM foods, so in 50 years-time we might discover that GM foods produce cancer cells.

While at times identifying that biotechnology might have some advantages, students using the health concerns ethical argument identified health risks associated with the use of a biotechnology as being a significant impediment to the adoption of the technology.

#### **6.2.1.4 Not Natural**

Comments that incorporated the phrase 'not natural' or 'unnatural' were categorised as 'not natural' ethical arguments. Sixty (41%) students used this ethical argument, which included comments such as:

It's *not natural* and things like this should be left alone. [emphasis mine] (357)

I don't like the fact that it's *unnatural*. [emphasis mine] (357)

What will happen to the baby when he/she grows up and finds out their beauty is *not natural*. [emphasis mine] (408)

Students at times presented a hierarchy of unnaturalness, as the following comment demonstrates:

Children should be a combination of 2 parents genetic material and even 'unnatural' techniques such as IVF allow for this: Cloning, in my understanding, does not involve both parents – therefore much more 'unnatural'. [emphasis student's] (304)

Unnatural was universally considered to be a bad thing that would probably cause further harm in some way:

It is unnatural & could have numerous bad side-affects, which could become passed onto future generations.

Being unnatural was often associated with being artificial, not real, or fake, with one student even considering a baby ‘not real’ if it had been produced using biotechnology:

Unnatural birth through cloning does not create a real being, but somewhat of a more ‘human robot’. (200)

... I think too much use [of genetic engineering] might bring us to live in a fake world. (402)

Comments that included the phrase or idea that biotechnology was ‘not natural’, such as those described above, were classified as a ‘not natural’ ethical argument.

#### **6.2.1.5 *Playing God***

Students’ arguments that involved playing God were generally a reference to the idea that, as humans, we are usurping God’s authority or stepping into His sphere of influence. This ethical argument was used by 54 (37%) students and implied that God has rights and privileges over issues of creation, life and death with which man should not interfere with. To ‘play God’ was considered an affront to God’s authority, and would probably have negative consequences. This idea was also expressed as ‘God’s responsibility’. It is an overarching idea that was frequently incorporated with the other ethical arguments identified in the students’ responses. Students often commenced or concluded their reasoning with the phrase ‘playing God’, and this has allowed an insight into what the students meant by the term.

One student commented that, “They are trying to be God” (160), expressing the core idea portrayed by students who used the term ‘playing God’. For many of the students, this attempt to ‘be God’ is wrong as they feel that God has certain rights and privileges with which humans are not permitted to interfere:

I think that we should leave it to God, he was the one who created us, so why should we choose how another human being looks like. We should not play God and I think that’s final. God’s Will will still rule before everything. (403)

If the technology was perceived as stepping into God’s domain of responsibility, it was considered an affront to His authority:

Again, this is playing the role of God and we should not, and do not have that authority. (403)

It was generally felt that the consequences of crossing God’s authority would have negative effects on those involved:

Once again playing God and taking matters into our own hands can have devastating effects not only for the clone but for the family around them. (411)

Even students who scored low on the religious belief scale expressed their concerns using the language of ‘playing God’, although they lacked any of the religious sentiments often expressed by those in the high level of religious belief group. This is evident through the comment made by one individual, who scored low on the CRBS, suggesting, “[pre-embryo genetic screening is] playing God, good traits should only be selected by luck” (198). For some students then, the phrase ‘playing God’ does not have theological significance, but rather is a placeholder for the idea that something is not natural.

#### **6.2.1.6 *God is Creator***

For many Christians, all life has a special value because God created it and, in addition, Christianity teaches that humans are created in the image of God. There is therefore a clear theological argument, which has been previously discussed in the literature review (Section 2.6), that biotechnology could be considered morally wrong because it changes what God created and, as fundamentalist Christians are taught, God created everything perfectly.

Many students (45, 31%) argued that, because God is the creator of all life, scientists do not have the ‘authority’ to change it. Or, as one student described their concerns;

God created the earth not man; so it is God who should have the right to change his creation not us. He made everything the way it is for a reason. (322)

While recognising the benefits of biotechnology for assisting in fulfilling their Christian duty to help alleviate suffering, some students were still very cautious about giving support for its use because of their concerns about ‘God is Creator’:

As a Christian I believe we should do everything we can to help others but is this it [...] if God created us like this, why should we need to change anything in the first place. (353)

Plants, although they are living things, do not have the ability to reason or feel like humans (or animals). If genetically modifying plants helps in the fight against world hunger, than I agree with it. However, plants are still God’s creation and I am a little hesitant about tampering with their genetic make-up. (306)

The evidence provided by the students for the ‘God is Creator’ argument was the biblical account of creation, found in the book of Genesis, which describes how God

was the creator of all things. Specifically referred to was the notion that what God created was good, “God saw all that He had made, and it was very good” (Genesis 1:31, NIV). The following student quote provides a direct link to this idea; however, students more commonly made inference to the biblical quote without actually mentioning it:

Plants ultimately belong to God & when God created plants he said ‘it was good’ so then, what right do we have to go play God & mess with genes. (416)

Students had concerns about the modification of plants because it altered what God, as the Creator of plants, had made. They felt that any modification was unnecessary because God made them ‘perfect’ to start with:

I don’t think that genetically modifying food is needed, because it isn’t natural, and it isn’t the way God made the food in this world. (183)

Some students further suggested that genetically modified food would inexorably be worse, reasoning that, if the plants could be improved, then God would have done that when He created them:

God, when he made the planets and stuff, he like did it for a reason, so like for us to go putting [genes] in canola it changes the whole eco system. (Sarah)

If God wanted us to just accept any kidney or organ then we wouldn’t have an immune system that doesn’t allow certain genes and organs work. (349)

Typically, the reaction to the use of gene technology in humans was much greater than that for plants, both in the number of students who disagreed with its use and also in the stronger language that was used to express their objections. This supports the previous data presented in Section 4.10, which suggests that students were more accepting of biotechnologies involving plants rather than humans. This could be because, as one student commented, “There is a line between food and life”. (348)

Students using the ‘God is creator’ ethical argument used their belief that God is the creator of all things to reject biotechnologies associated with plants and humans. This ethical argument used a biblical reference as the basis for the objections and suggested that the technologies took power away from God and placed it in the hands of scientists. Students using this argument were concerned that, because God created living things perfectly in the first place, it would not be possible to make them better. Consequently, they believed that any change to creation by humans would not be beneficial in the end.

### 6.2.1.7 *God's Will*

References to 'God's will' or 'God's plan' were made throughout the interviews and the questionnaire responses (29 Students, 20%). This ethical argument is exemplified by the student who commented that:

But no matter how much man tampers with what God has set in place, God has a larger plan for the future and man cannot alter that plan. (317)

Whether the student meant that man literally *cannot* alter God's plans or that he *should not* alter God's plan is not made clear, although the latter is more logical. If the student believed that it is not possible to alter God's plan, then no technology would be able to do so.

Students often equated 'God's will' with what would 'naturally' happen. The idea was put forward that God's way is the natural way:

More creating a designer baby than letting nature take its course which is what God intended. (Brendon)

All embryos (life, babies) have equal value to God & all deserve equal chance at life. We have no right to decide which lives or dies. It is up to God & we should let his will be done & for *nature to happen naturally*. (416, emphasis mine)

The interviews provided a further opportunity to explore in detail the ethical argument 'God's will' as it allowed for the interaction of ideas.

Students were presented with a scenario in the interviews that pushed the limits of what might be considered 'God's will'. One of the ethical dilemmas, a copy of which is presented in Appendix B, gave the example of a mother whose husband and only child were killed in a car accident. The mother wants to take cells from her child to grow a clone so that she could have another child who would be the product of herself and her late husband. The 'God's will' argument implies that God planned for the child to die in a car accident. Some students insisted that this was part of God's plan. However, others made an attempt to justify God's actions by suggesting that, although something bad had happened to the mother (she lost her child and husband), she would somehow be compensated for this later in her life:

God's got a plan for everyone and then you can't really change the plan. If the car accident was going to happen, then it was going to happen. There are probably other good things that are going to happen in her life. (Aaron)

Not all students were prepared to accept the death of a child as being part of God's will and, when this was suggested by Chris in the second interview, Samuel challenged Chris about this idea:

Chris        Because whatever God has planned for us he obviously planned the death of her baby.

Samuel      (interrupting) I think we have to be careful with that, I don't think it is God's plan that the baby died there are, you know, we do realise that because of sin there is death and, (pause) for her it is a tragedy that she lost her son but I guess that's life and we have to deal with that with certain things.

Kate         I agree with [Samuel], (pause) it's not right, I don't know, I can't explain it, (pause) it's just not right.

Chris        (Backing away from his initial position) whatever happens, happens, we should not try and reverse it.

As identified in the Section 2.6, these students are not alone in their struggle to rationalise the sometimes-confronting ideas of God's will and the pain and suffering they observe in the world.

#### **6.2.1.8 Human Embryo**

Discussions regarding the moral status of the embryo are central to many of the objections by religious groups to biotechnologies involving humans, and a total of 25 (17%) students used this ethical argument. The Christian origins of this ethical argument have been identified in Section 2.6.1.1 and it is not surprising that many of the more religious students were opposed to the use of any technology that might harm or destroy a human embryo because they viewed an embryo as being fully human and therefore having the same rights as a human:

I consider the embryo to be a baby and if someone were to experiment on an embryo, then they are also experimenting on a baby. (118)

I see the positives in this and would generally agree with it except for the making of an embryo. Embryos have the potential to be a human life- how can we kill it so we can live? If the same technology could be used without the use of an embryo then I would support such technology, but I can't condone the killing of an embryo-even a clone- for some other use. (197)

After a discussion on the fate of unused embryos in one of the interviews, Samuel concluded that "from my religious background I would say that [IVF and embryo selection] is wrong because life is life from conception". This represents the view of many Christians who consider human life to begin at conception. Lawrence

expressed a different perspective, referring to another commonly held view that life begins at some time after conception:

The embryo is not really human until God breathes on it so everyone's got different opinions on this but I believe it could be used for research.  
(Lawrence)

An interesting discussion took place in the third interview when students were exploring the use of human embryos for research. Here we see a range of different views about the state of the embryo represented:

Craig     Destroying an embryo is, I guess to me, I don't really see much of a problem with it, it's not like you're killing a baby it's sort of like a baby in the process.

Simon     But how can it be a potential life if it can't feel anything and you're not certain that the embryo will turn out to be a baby anyway.

Melissa   It's just a beginning.

Craig     As a person you look at something when you see arms legs a face and all that when the baby starts to take shape you think well it's a life now.

Melissa   I think it's a life but I don't consider it as [having] human characteristics until you can actually see it as human. Before that it's OK, because there is a lot of things like miscarriages and abortions so if that is OK then this should be OK.

Craig     I don't really consider anything human until they have consciousness, if they can't express themselves then what makes them different from this cup [holds up the cup of juice he is holding].

The 21 students who were not identified as having a Christian worldview were typically not concerned about the use of human embryos in research. One student made this point very clearly when he wrote:

[non reproductive cloning] will improve the quality of life for those who ARE ALREADY LIVING. An embryo is not a complete human as yet, therefore it can and should be used to save living humans life. This is a very good idea and I strongly agree. [emphasis student's] (413)

Of the 117 students who accepted a Christian worldview, 25 students (17%) totally rejected any experimentation on human embryos, or any technique that might result in their deliberate destruction. However, just as different interpretations exist amongst adult Christians, so too the students presented different ideas about when an embryo obtained a soul or had a moral status equivalent to a newborn child. The



concerns about the use of embryos in biotechnology provided considerable debate and some strong opinions, but it was also evident that some students were struggling to identify at which point an embryo should be considered fully human.

#### **6.2.1.9 Uniqueness of Individuals**

One direct result of the revered view of human creation that was evident in the ethical argument ‘God is creator’ is the importance that was placed on the uniqueness of an individual as being a gift from God. This results in the rejection of anything that undermines human uniqueness. A number of students (24, 16%) felt that the uniqueness of an individual was a God-given characteristic of humans:

I don’t believe it is right to clone people because God made everybody different. (327)

I don’t think there is a need for clones. We are still god’s children and he made us in his image. We should enjoy our individuality. (348)

Ethical arguments incorporating uniqueness were also applied to Genetic Enhancement. It was felt that the unique characteristics given to the individual by God would be jeopardised if parents could add any desired traits to their child, as the following comment highlights:

I think God creates us all in his own ways with certain characteristics and physical features he creates us as individuals (334)

Concerns about the uniqueness of individuals was also expressed by students with a relatively low level of religious belief (i.e. they scored low on the CWS) as the following comments show:

No more uniqueness among humans. The stories of how disabled people overcome their struggle is always a good source of inspiration. (167)

I don’t think this is good. You should not be able to choose your child’s characteristics. Your child is special because it is yours, it may have your eyes and hair colour or your wife’s nose and ears. People can tell the child is yours and they fit into a family better. Being able to forcefully change this would take away the special feeling that comes from childbirth. (305)

While the uniqueness ethical argument was not confined to students with a Christian worldview, students who used this argument were typically concerned about cloning and pre-implantation genetic screening because they felt that it undermined the idea that God made everyone different, including their physical characteristics and other

abilities or talents. They were often confident that those lacking in some area would be compensated with other gifts or abilities.

#### **6.2.1.10 *Slippery Slope***

The slippery slope analogy is frequently encountered when biotechnologies are being discussed. It suggests that, while the use of the technology under examination might not be intrinsically wrong, it could result in an action or a decision being made that is ethically wrong or undesirable.

Six (4%) students employed this type of reasoning in their responses. Two quotes provide examples of this ethical argument:

[pre-embryo genetic screening is] allows parents to play God and the child could be aborted if they're found to have a genetic disease. (153)

My other concern is [that] genetically changing food can be considered 'playing God' although at the moment I don't think changing plants DNA is much of a problem I am concerned that people may use it as justification to do things that would be against God. (197)

Students used the argument of slippery slope from a religious perspective when they felt that the technology would inevitably result in another action that they felt was morally wrong from the perspective of their religious faith. The consequence that was of most concern to students was the destruction of human embryos.

#### **6.2.1.11 *Science and Religion***

An understanding of the relationship between Science and Religion, and in this case Science and Christianity, is central to any discussion that brings together these two domains. The question regarding whether it is religion or science that is the ultimate arbitrator of truth is critical in determining the role that religious beliefs can play in socioscientific issues.

Students who provided a comment regarding the relationship between Science and faith aligned with two broad categories, namely, those individuals who felt that religion limits science and interferes with the progress of science, and those students who felt that science and scientists are in conflict with the moral teachings of their faith, and such biotechnologies should not be pursued.

#### 6.2.1.11.1 Religion Limits Science

Three students (2%) took exception to the control that religion has had over scientific advancement. While taking a strong humanitarian position in their support for genetically modified crops, the following student suggested that:

We need to concentrate on helping those who are hungry and sick, rather than whether it's interfering with religious beliefs. (413)

Another student, commenting on the use of stem cells for research, used much stronger terminology stating:

Stem cell research is really important and the many ethical issues around it are stupid and are only stalling our ultimate progression. Religion tends to get in the way it's the source of all world conflicts it incites war and prevents humanity from progressing. It is a roadblock to having a perfect society. (406)

#### 6.2.1.11.2 Science Disregards Faith

In contrast to the three students described above who were critical of any religious control of scientific progress, there were other three (2%) students who felt that scientists were overstepping their authority or that science was disregarding their faith-based principles. These comments were often as critical of scientists as they were of the science itself. While identifying the possible good in the technology, the following students were adamant in their rejection of it; they clearly had a low opinion of scientists and their ability to make good decisions about the use of the technology:

It's good to prevent disease, but anything else seems wrong! Scientists might actually screw up even more even if they think they know what they are doing. (410)

[...]if the screening is used to select the 'perfect' child or to get specific gene characteristics I disagree strongly and think the scientists have overstepped ethical bounds. (199)

### 6.2.2 **Student Engagement in Ethical Arguments**

The quality of the responses to the dilemmas presented in the questionnaire varied greatly, with some students writing very little or nothing, while others provided a detailed analysis of the issues being investigated. Likewise, in the interviews, some students were more willing to share their thoughts than others. It was evident that some of the students had thought deeply about their responses and, although they sometimes struggled to come to a definitive conclusion regarding the issues, they provided sophisticated analyses and examined the issues for and against the

implementation of the biotechnologies presented. It was especially evident in the interviews that students found it challenging to decide what was right and what was wrong in these scenarios. Their arguments were often disconnected, and sometimes even contradictory, as they struggled to synthesise and voice their opinion on topics that most of them had never considered before. It was also evident that they understood that these were complex problems and that a different individual would bring to the problem their own set of beliefs and experiences, and therefore possibly come to different conclusions. Students frequently premised their statements with the comment “in my view” or “my belief” or “it’s their choice”. While opinions differed about the conclusions, the one consensus, either explicitly made or implied, was that dealing with these types of ethical problems was a challenge. As Samantha commented at the end of her interview: “That really made me think”.

### **6.2.3 Frequency of Ethical Arguments in Student Reasoning**

To better understand the contribution of each ethical argument to students’ reasoning about biotechnology, it was appropriate to consider the frequency with which students used each of the twelve ethical arguments. This was done separately for each of the four dilemmas: GM Food, Pre-implantation Genetic Screening, Reproductive Cloning, and Therapeutic Cloning. In addition, the frequency of the total number of comments that used the ethical argument, as well as the number of students who used the ethical argument at least once, was calculated and is reported in Table 6.1.

The number of students using each ethical argument was often very low; however, the ethical arguments ‘playing God’, ‘God is Creator’, and ‘Gods will’, ‘social justice’, ‘health concerns’, ‘health benefits’ and ‘not natural’ were all used by more than 20% of respondents. The use of the ethical arguments varied across the four dilemmas; ‘playing God’ was associated mostly with Pre-implantation Genetic Screening (PGS) and Reproductive Cloning (R. Clone); ‘Gods will’ was used less frequently than some ethical arguments but was used across most of the dilemmas; ‘God is Creator’ was associated more frequently with Genetically Modified Food (GM Food) and Pre-implantation Genetic Screening. The ‘social justice’ ethical argument was used almost exclusively for when students discussed Genetically Modified Food; however, ‘health concerns’ was associated more with Genetically Modified Food and Reproductive Cloning and ‘health benefits’ was associated with

Pre-implantation Genetic Screening and Therapeutic Cloning (T. Clone). Finally, the ‘not natural’ ethical argument was commonly used for all except the Therapeutic Cloning dilemma.

#### **6.2.3.1 *Genetically Modified Food***

The most commonly used ethical arguments in the Genetically Modified Food dilemma were: ‘social justice’, which was used by 62 (42%) students and was the most commonly used ethical argument for any particular ethical dilemma, ‘health concerns’ which had 31 (21%) students, ‘not natural’ with 23 (16%) students, and ‘God is Creator’ which had 16 (11%) students using it.

#### **6.2.3.2 *Pre-implantation Genetic Screening***

Commonly used ethical arguments in the Pre-implantation Genetic Screening dilemma included ‘playing God’, which 29 (20%) students used, and ‘health benefits’, which 30 (20%) of the students used. Students also used the ethical arguments ‘God is Creator’ and ‘not natural’, both of which were used by 19 (13%) students.

#### **6.2.3.3 *Reproductive Cloning***

The ethical arguments most frequently used in the Reproductive Cloning dilemma were ‘health concerns’, with 15 (10%) students, ‘playing God’ and ‘not natural’, both with 14 (10%) students, and ‘uniqueness’, which was used by 12 (8%) students.

#### **6.2.3.4 *Therapeutic Cloning***

Ethical arguments that included ‘health benefits’ were used by 41 (28%) of the students when responding to the Therapeutic Cloning dilemma, and 15 (10%) students identified the moral status of the human embryo as an ethical argument against the use of therapeutic cloning.

### **6.2.4 Summary of Ethical Arguments in Students’ Reasoning**

This section has presented a description of the ethical arguments used by students and, in part, answers the third research question: How are students’ religious beliefs incorporated into their informal reasoning about biotechnology? A total of 12 ethical arguments were identified: ‘religion limits science’, ‘science disregards faith’, ‘playing God’, ‘slippery slopes’, ‘God’s will’, ‘human embryo’, ‘God is Creator’, ‘uniqueness’, ‘social justice’, ‘health benefits’, ‘health concerns’, and ‘not natural’.

Student engagement in the process of moral reasoning identified the diversity of thoughts and the challenges faced by students when reasoning about socioscientific issues associated with biotechnology.

#### **6.2.5 Key Findings of Ethical Arguments in Students' Reasoning**

This section has identified the seven ethical arguments more commonly used by students when making moral judgements about biotechnology. These ethical arguments were 'health benefits', 'social justice', 'health concerns', 'not natural', 'playing God', 'God is Creator' and 'God's will'. It was also shown that the use of the ethical arguments was dependent on the context of the biotechnology being investigated, with some ethical arguments used only in a limited number of dilemmas. The ethical argument 'health benefits' was not typically used in the Reproductive Cloning dilemma and 'not natural' was typically not used in the Therapeutic Cloning dilemma. The 'social justice' ethical argument was predominantly limited to the Genetically Modified Food dilemma, while 'playing God' and 'God's will' were generally only used for the dilemmas Pre-implantation Genetic Screening and Reproductive Cloning.

### **6.3 ETHICAL ARGUMENTS AND BIOTECHNOLOGY ATTITUDES.**

To obtain a more complete understanding of students' use of the 12 different ethical arguments, it was necessary to compare the attitudes towards biotechnology of the students who used each of the ethical arguments with those who did not. This also provides a determination of the statistical significance of that ethical argument in determining students' attitudes towards biotechnology.

#### **6.3.1 Analysis of Ethical Arguments and Biotechnology Attitudes**

To determine whether there was any relationship between the use of the twelve ethical arguments and attitudes towards biotechnology, the mean Christian Attitudes Towards Biotechnology Scale (CATBS) scores were compared between those students using each of the ethical arguments and those not using the ethical argument. Table 6.3 shows the results when independent *t*-test was performed for each of the twelve ethical arguments with 'uses the ethical argument in reasoning' (EA used) and 'does not use ethical argument in reasoning' (EA not used) being the grouping variables, and the CATBS being the test variables. Effect sizes were also calculated (Hedges' *g*) so that an estimate could be made of the magnitude of the differences.

This allowed a comparison to be made between students exhibiting evidence of the ethical argument and those who did not.

Table 6.3 *Differences in Use of Ethical Arguments and the Combined Attitudes Towards Biotechnology Scale (CATBS) Showing Item Mean, Standard Deviation t-Test and Effect Size*

Ethical argument	CATBS Mean		CATBS SD		Difference	
	EA used	EA not used	EA used	EA not used	Effect Size <sup>a</sup>	<i>t</i>
Health Benefits	2.58	2.31	0.41	0.47	0.621	3.88***
Social Justice	2.61	2.29	0.44	0.44	0.727	4.65***
Health Concerns	2.23	2.46	0.46	0.46	0.500	2.11*
Not Natural	2.16	2.49	0.37	0.46	0.775	4.04***
Playing God	2.25	2.46	0.46	0.46	0.457	2.45**
God is Creator	2.20	2.47	0.37	0.47	0.611	3.14***
God's Will	2.09	2.46	0.38	0.45	0.846	3.44***
Human Embryo	2.45	2.41	0.46	0.47	0.085	0.34
Uniqueness	2.44	2.41	0.48	0.46	0.065	0.28
Slippery Slope	2.28	2.42	0.25	0.46	0.308	0.60
Religion limits science	3.45	2.40	0.08	0.45	2.349	4.08***
Science disregards faith	2.20	2.42	0.18	0.47	0.471	0.79

Note. EA used = ethical argument used; EA not used = ethical argument not used. For a breakdown of the frequency of students using each ethical argument refer to Table 6.2

<sup>a</sup>Hedges' *g*.

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$

### 6.3.2 Summary of Ethical Arguments and Biotechnology Attitudes

Results in Table 6.3 show that statistically significant differences in students' attitudes towards biotechnology, as measured by the CATBS, exist for eight of the twelve ethical arguments identified in the study. These results, shown in Table 6.3, show that for students who used the ethical arguments 'health benefits', 'social justice', 'not natural', 'God is creator', 'God's will', or 'religion limits science' had statistically significant differences ( $p < 0.001$ ) in their CATBS when compared to students not using those ethical argument. Significant differences were also found for, 'playing God' ( $p < 0.01$ ), and 'health concerns' ( $p < 0.05$ ). The ethical arguments 'health benefits', 'social justice', 'health concerns', 'not natural', 'God is creator', and 'religion limits science' had large effect sizes, while 'God's will' had a medium effect, using Cohen's (1988) criteria.

### **6.3.3 Key Findings of Ethical Arguments and Biotechnology Attitudes**

These data provide evidence that students who use the ethical arguments ‘health concerns’, ‘not natural’, ‘playing God’, ‘God is Creator’, ‘God’s will’, and ‘religion limits science’ will on average have a more negative attitude towards biotechnology. Conversely, students who use the ethical arguments of ‘health benefits’, ‘social justice’, and ‘religion limits science’ on average show more support for biotechnology.

## **6.4 USE OF ETHICAL ARGUMENTS AND RELIGIOUS BELIEF.**

To further deduce how students were incorporating their religious beliefs in moral judgement, as represented by the twelve ethical arguments, it was necessary to compare the level of religious belief of those students who used each of the ethical arguments with those who did not. This also provides statistical evidence for whether the ethical arguments have a religious basis or not.

### **6.4.1 Analysis of Ethical Arguments and Religious Belief**

To determine the relationship between use of the 12 ethical arguments and religious belief, the mean Christian World View Scale (CWS) scores were compared between those students who used a particular ethical argument and those who did not use it. Table 6.4 shows the results of an independent *t*-test for each of the twelve ethical arguments with ‘uses the ethical argument in reasoning’ (EA used) and ‘does not use the ethical argument in reasoning’ (EA not used) as the grouping variables, and the CWS as the test variables. Effect sizes were also calculated (Hedges’ *g*) so that an estimate could be made of the magnitude of the differences. This allowed a comparison to be made between students using the ethical argument and those who did not.

### **6.4.2 Summary of Ethical Arguments and Religious Belief**

The results show that statistically significant differences in student religious worldview, as measured by the CWS, existed for three of the twelve ethical arguments identified in the study. From the results reported in Table 6.4 it can be seen that the ethical argument, ‘God is Creator’ has statistically significant differences at  $p < 0.001$  and ‘not natural’ and ‘God’s will’ have significant differences at  $p < 0.01$ . The ethical argument ‘not natural’ had medium effect while ‘God is Creator’ and ‘God’s will’ had a large effect, using Cohen’s (1988) criteria.



Table 6.4 *Differences in the Christian Worldview Scale (CWS) and Use of Ethical Arguments Showing Item Mean, Standard Deviation, t-Test and Effect Size*

Ethical argument	CWS Mean		CWS SD		Difference	
	EA used	EA not used	EA used	EA not used	Effect Size <sup>a</sup>	<i>t</i>
Health Benefits	3.70	3.85	1.126	0.93	0.142	0.88
Social Justice	3.63	3.90	1.15	0.89	0.264	1.72
Health Concerns	4.02	3.70	0.95	1.01	0.325	1.87
Not Natural	4.14	3.69	0.77	1.05	0.476	2.50**
Playing God	3.91	3.76	0.84	1.05	0.153	0.739
God is Creator	4.33	3.67	0.59	1.05	0.706	3.50***
God's Will	4.31	3.72	0.56	1.04	0.611	2.48**
Human Embryo	3.90	3.78	1.08	1.00	0.118	0.52
Uniqueness	4.00	3.76	1.03	1.01	0.237	1.07
Slippery Slope	4.30	3.78	0.48	1.02	0.517	1.01
Religion limits science	2.74	3.81	1.58	0.99	1.069	1.83
Science violates faith	4.65	3.78	0.23	1.01	0.867	1.49

Note. EA used = ethical argument used; EA not used = ethical argument not used. For a breakdown of the frequency of students using each ethical argument refer to Table 6.2

<sup>a</sup>Hedges' *g*.

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$

#### 6.4.3 Key Findings for Ethical Arguments and Religious Belief

These data provide evidence that students who use the ethical arguments involving 'not natural', 'God is Creator', and 'God's will' have, on average, a higher level of religious belief. This analysis did not find a statistically significant difference in the level of religious belief between those students who used the ethical argument 'playing God' and those who did not.

#### 6.5 DEVELOPMENT OF THE REASONED RELIGIOUS BELIEF LEVEL

Analysis of the students' responses to the BARBQ<sup>qual</sup> showed that some of the students' statements featured information that referred directly to their religious belief system. The extent to which belief systems were incorporated into a response was used to determine a statement's Reasoned Religious Belief Level (RRBL). This represents a measure of the extent to which students used their religious beliefs as part of their reasoning process. Before analysis, all samples that did not include any written responses to the ethical dilemma questions on the questionnaire were

removed from the sample. This resulted in 147 students who responded to at least one of the dilemmas. As for previous data analysis, *comment* was used to describe the student's written thoughts to one of the ethical dilemmas, while *response* was used to describe all of the written comments made by the student. All comments were scored on a four-point scale that corresponded to the level of religious belief that was integrated into that comment. A description and exemplars of each Reasoned Religious Belief Level is provided in Table 6.5. Those comments that showed no indication of reasoned religious belief, that is, they included no reference to God, religion, Christianity or faith, were allocated a Reasoned Religious Belief Level of 0. Those comments that were deemed to have a negative religious belief were allocated a Reasoned Religious Belief Level of -1; these comments included specific reference to a disbelief in God, or referred to religion, Christianity or faith in a negative way. A level of +1 was assigned to comments that included reference to God, religion, Christianity or faith but provided no evidence that specific Christian or faith principles had been considered or incorporated into the reasoning processes. The level +2 was assigned to responses that included reference to specific Christian or faith principles in the reasoning processes.

#### **6.5.1 Analysis of Students' Reasoned Religious Belief Level**

To complete the analysis relevant to the third research question, the frequency of students using each Reasoned Religious Belief Level was examined. This allows an understanding of the extent and depth to which students included religious beliefs and ideas into their informal reasoning about biotechnology. Table 6.6 shows the frequency of the RRBL, broken down according to each dilemma, as well as the total number of students who included at least one comment at that level. The number of comments for each of the RRBLs is also shown in this table. Because of this non-independence between levels of RRBL, it was considered inappropriate to compute inferential statistics to determine differences. Instead the number and percentage of students who employed each level of religious reasoning at least once are presented for each of the four dilemmas.

Table 6.5 *Description and Exemplars of Each Reasoned Religious Belief Level*

RRBL	Description	Examples
-1	Reasoning includes specific reference to a disbelief in God or refers to religion, Christianity or faith in a negative way.	<p>We need to concentrate on helping those who are hungry and sick, rather than whether its' interfering with religious beliefs. (413)</p> <p>Stem cell research is really important and the many ethical issues around it are stupid and are only stalling our ultimate progression. Religion tends to get in the way it's the source of all world conflicts it incites war and prevents humanity from progressing. It is a roadblock to having a perfect society. (406)</p>
0	Reasoning includes no reference to God, religion, Christianity or faith.	<p>I think that children should be luck of the draw. You should just be happy with whatever comes out. (339)</p> <p>These people are ill and need help – I see no difference doing this than getting an organ transplant. This would be more beneficial for the community. (314)</p>
1	Reasoning includes reference to God, religion, Christianity or faith but provides no evidence that specific Christian or faith principles have been incorporated into the reasoning processes.	<p>Selecting the gender of a child should be up to God and God alone. (410)</p> <p>It is God's decision for the couple to have a baby or not. (163)</p>
2	Reasoning includes reference to specific Christian or faith principles that are incorporated into the reasoning processes.	<p>All embryos (life, babies) have equal value to God &amp; all deserve equal chance at life. We have no right to decide which lives or dies. (416)</p> <p>Personally I think God has his hand on everything &amp; we should not worry too much unless he specifically says so. (341)</p>

Table 6.6 *Frequency of Students' Reasoned Religious Belief Level (RRBL) for Each Ethical Dilemma, Total Comments and Total Students*

RRBL	GM Food <sup>a</sup>		PGS <sup>a</sup>		R. Clone <sup>a</sup>		T. Clone <sup>a</sup>		Total <sup>b</sup> (comments)		Total <sup>a, c</sup> (Students)	
	f	%	f	%	f	%	f	%	f	%	f	%
Level -1	2	1	0	0	0	0	1	1	3	1	3	2
Level 0	114	78	85	58	99	67	93	63	391	78	140	95
Level 1	17	12	43	29	20	14	14	10	94	19	56	38
Level 2	6	4	7	5	2	1	1	1	16	3	11	7
No Response	8	5	12	8	26	18	38	26	84	17	0	0

Note. GM Food = Genetically Modified Food; PGS = Pre-implantation Genetic Screening; R. Clone = Reproductive Human Cloning; T. Clone = Therapeutic Human Cloning; f = the number of students at each RRBL.

<sup>a</sup>n = 147 students. <sup>b</sup>n = 588 comments. <sup>c</sup>Total (students) represents the number of students using the RRBL at least once.

### 6.5.2 Summary of Students' Reasoned Religious Belief Level

Many students had responses that fell into two or more categories. For example, a student might have used reasoning that did not invoke a reference to God or religion in one dilemma, but in a different dilemma they did reference God. The *total (students)* described in Table 6.6 is the number of students who used a given level of reasoned religious belief (RRBL) for at least one of the ethical dilemmas and is therefore necessarily less than the sum of the four ethical dilemmas for each level of reasoned religious belief, which is shown in the *total (comments)* of Table 6.6. In the sample, there were 588 comments from 147 students.

While the majority of comments (391, 78%) did not make any explicit or implied reference to God, faith or religion, there were still a substantial number of students (56, 38%) who did explicitly include religious ideas or terminology in at least one of their comments. Of these responses, most consisted of only a reference to God or faith 56 (38%) students and 94 (19%) comments, and only a few, 11 (7%) students and 16 (3%) of comments, included any evidence of specific faith-based principles in their reasoning about the appropriateness of biotechnology. All of the students who included arguments at RRBL 2 also used arguments at RRBL 1. A small minority of all comments (3, 1%) made reference to faith in a negative manner, and

demonstrated a distinct rejection of religious belief along with any role for religious faith in moral judgements regarding ethical decisions about biotechnology.

Although a large proportion of respondents (117, 60%), were identified as having a high level of religious belief, according to the CWS (Section 4.6), significantly less students (56, 38%) incorporated religious or faith ideas into their responses. Those students who did incorporate religious ideas into their reasoning often did so for only one or two of the ethical dilemmas, which is evident from the much lower frequency of reasoned religious belief in the total comments, when compared with the total students using reasoned religious belief. Only seven (5%) students incorporated religious ideas in all of the dilemmas to which they responded. No particular dilemma appeared to be more likely than another to invoke a religious response; however, Pre-implantation Genetic Screening did incorporate more level-one comments (43, 29%) than the other three dilemmas, which had between 14 (10%) and 20 (14%) comments at RRBL 1.

### **6.5.3 Key Findings for Students' Reasoned Religious Belief Level**

The data analysis presented in this section has demonstrated that many of the students identifying with a Christian worldview did not incorporate religious ideas into their reasoning about biotechnology issues. When they did refer to religious beliefs or use religious terminology, it was typically for only half of the dilemmas, and in rarely included reasoning that made reference to specific Christian or faith principles.

## **6.6 SUMMARY OF CHAPTER AND KEY FINDINGS**

Twelve ethical arguments that were used by students in the questionnaire and interviews when reasoning about biotechnology issues were identified and presented in this chapter. Chapter 6 also presented the statistical analysis of the ethical arguments, and provided data on the frequency with which students incorporated religious ideas and terminology into their reasoning about biotechnology.

Following the introduction, Section 6.2 described 12 ethical arguments that were identified in the students' responses to the four ethical dilemmas and the semi-structured interviews. The frequency with which the ethical arguments were used was quantified, showing that, although the use of an ethical argument was context-dependent. Ethical arguments involving 'health benefits', 'social justice', 'health

concerns', 'not natural', 'playing God', 'God is Creator' and 'Gods will' were most commonly used by students.

Section 6.2 analysed students' thinking about biotechnology, and showed that students' use of the ethical arguments 'health concerns', 'not natural', 'Playing God', 'God is Creator', 'Gods will' and 'science disregards faith' are statistically linked with negative attitudes towards biotechnology. Students use of the ethical arguments 'health benefits', 'social justice' and 'religion limits science' were statistically linked with support for biotechnology.

Section 6.3 analysed students' religious beliefs and showed that the ethical arguments involving 'not natural', 'God is Creator' and 'God's will' are associated with a Christian worldview.

Section 6.4 discussed the development of the Reasoned Religious Belief Level measure, and presented an analysis of the frequency of those levels within students' reasoning. It was shown in this section that most students provided few connections to their religious worldview, and rarely did they incorporate religious principles or ideas into their reasoning.

This chapter concludes a presentation of the data and analyses that are relevant to answering the three research questions that were the focus of this study. The results have been presented over the preceding three chapters. Chapter 4 presented an analysis of the data pertaining to whether Christian religious belief is a predictor of attitudes towards biotechnology. Chapter 5 presented the data analysis corresponding to the second research question: Does the acceptance of a Christian belief affect student's patterns of informal reasoning? Chapter 6 also presented an analysis of the data that corresponded to the third research question, how are students' religious beliefs incorporated into their informal reasoning about biotechnology? The next chapter discusses each of the three research questions with respect to the key findings presented in these three chapters.

## **Chapter 7**

### **DISCUSSION OF RESEARCH RESULTS AND FINDINGS**

#### **7.1 INTRODUCTION**

The main purpose of this doctoral study was to explore the role of Christian religious beliefs on students' attitudes and reasoning about biotechnology issues within three Victorian faith-based schools. To achieve this goal, three research questions were developed.

1. How does religious belief act as a predictor of attitudes towards biotechnology?
2. Does the acceptance of a Christian belief affect students' patterns of informal reasoning?
3. How are students' religious beliefs incorporated into their informal reasoning about biotechnology?

The previous three chapters have detailed the results of a systematic study that was designed to answer these questions. In this chapter, these results are synthesised and discussed within the context of the current literature and the three research questions central to this study. Section 7.2 discusses the division of the sample into students who have a high level of religious belief and those with a low level of religious belief. Section 7.3 discusses the implications of the data relevant to the first research question. Section 7.4 discusses the findings relevant to the second research question, and the third research question is discussed in Section 7.5. Section 7.6 of this chapter provides a general discussion of the research findings before the final section (Section 7.7) concludes with a summary of the chapter.

#### **7.2 HIGH AND LOW LEVELS OF RELIGIOUS BELIEF**

As outlined in Section 4.6, the sample was divided into two groups: students with a low level of Christian religious belief and students with a high level of Christian religious belief. The allocation of students into one of these two categories allowed comparisons to be made about the concerns that students had regarding biotechnological issues and their patterns of informal reasoning. The students who participated in this research attended a faith-based Christian School, and it was anticipated that the total cohort of students would be more religious than students in many schools. However, none of the participating schools rejected applications based

on religious belief and the results presented in Chapter 4 show that students who do not accept a Christian worldview are represented in the sample.

The subset of students representing a low level of Christian religious belief was defined in such a way as to limit that group to students who, on average, disagreed with the core principles of the Christian faith. This means that those students who partially agreed with some of the religious ideas might still be included in the sample. It is therefore appropriate to refer to this group of students who scored low on the Christian Worldview Scale (CWS) as having a low level of religious belief when compared to the whole sample. However, from the perspective of the wider community, which might include a greater percentage of individuals categorised as non-believers, some of the students categorised as having a low level of religious belief might still be more religious than the average student attending a public (government) school in a similar community, although it would still be much lower than what is considered mainstream Christianity.

Two other issues can be identified with the sample of students that has been classified as having a relatively low Christian religious belief. Firstly, the instruments used to measure students' Christian worldview were not designed to identify religious students who might reject a Christian faith, such as those from a Muslim background, and therefore score low on the CWS. Such students, and some are known to attend the participating schools, could share some of the same concerns about biotechnology, and for similar reasons; however, they would have been included in the low level of religious belief group of students. The second issue with the students classified as having a low level of religious belief is that a Christian philosophy is actively promoted and Christian doctrine taught to all students in the participating schools. It is therefore likely that the students who were identified as having a relatively low level of Christian belief would be more knowledgeable about Christian beliefs and doctrines than those students with a similar worldview who did not attend a faith-based school.

Students comprising the strong Christian religious belief group do not necessarily represent all Christian views about biotechnology. As the school is administered on behalf of a Christian church organisation that comes from a fundamentalist tradition, it is possible that this sample representing a high level of Christian belief is biased



towards fundamentalist Christian faith, which has been previously been shown to have more concerns about biotechnology.

### 7.3 FINDINGS FOR RESEARCH QUESTION 1

The first research question asked: How does religious belief act as a predictor of attitudes towards biotechnology? To answer this question, a quantitative approach was taken, so that any correlation between religious belief and attitudes towards biotechnology could be observed. However, before this question could be addressed, it was necessary to assess a number of key variables, identified in the literature, to ensure they did not undermine the subsequent findings of this research; the most significant of these was gender. It was shown that, even when gender differences were considered, religious belief decreased students' acceptance of biotechnology. More detailed analysis of the measures of religious belief confirmed an association between religious belief and attitudes towards biotechnology and identified which of the independent strands that measured a student's Christian worldview provided a statistically significant contribution to the variance found in students' attitudes towards biotechnology. When the level of concern about specific biotechnology issues was examined, it was found that the students in this study reflected the findings discussed in the literature, yet this study also clearly identified a difference in the level of concerns about those technologies between students with a high level of religious belief and those students with a low level of religious belief.

#### 7.3.1 Role of Gender and Subject on the Findings of Research Question 1

In a review of the literature (Section 2.3.3), it was suggested that a student's gender might impact on their attitude to biotechnology as well as their level of religious belief. It was also suggested that a student's level of interest in, and understanding of, science, reflected in the subjects studied, might correlate with students' attitudes towards biotechnology and, possibly, their religious belief.

##### 7.3.1.1 *Gender Differences*

The results of the analysis of gender differences on attitudes towards biotechnology and religious belief showed that, within the sample, females were more religious than their male counterparts. This conforms to the consistent findings of over a century of research in the field of sociology of religion that has demonstrated that females score more highly than males on nearly all measures of religiosity (Francis & Wilcox,

1996; Miller & Hoffmann, 1995; Sullins, 2006; Walter & Davie, 1998). It was suspected that a relationship between religious belief and attitudes to biotechnology might be influenced by the decreased acceptance of biotechnology by females as a result of their increased level of religious belief. Section 4.7 presented for both male and female correlations between the three scales of religious belief and the seven scales of attitudes towards biotechnology, along with the CATBS and the CWS. While there were some statistically significant differences between the genders for a number of the scales, the overall direction and size of the correlations were similar for both genders. This study has therefore demonstrated that there is a negative correlation between religious belief and attitudes towards biotechnology that exists independently of the correlations for females between low acceptance of biotechnology and being associated with a higher religiosity, although these two scales partially accounted for the correlation.

#### **7.3.1.2 Subject Differences**

Section 4.7 described the results for subject differences in the CWS and CATBS. Given that only one measure of religious belief and one measure of attitudes towards biotechnology had statistically significant subject differences, it is likely that studying Biology had only a limited, if any, effect on students' attitudes towards biotechnology or their level of religious belief.

While an increased appreciation of science might explain chemistry students' better understanding of biotechnology when compared to their peers, the small sample size does not justify any conclusions regarding this or the observation that chemistry students showed, on average, a greater level of religious belief.

#### **7.3.2 Associations between Belief and Biotechnology Attitudes**

An analysis of the associations between religious beliefs and attitudes towards biotechnology demonstrates that religious belief acts as a general predictor of attitude towards biotechnology. Students who measured high on the Christian Orthodoxy, Biblical Literalism and Religiosity scales were more likely to have a negative attitude towards biotechnology. In the cognitive strand, students' understanding about biotechnology (Biotechnology scale) was not significantly correlated to any of the measures of religious belief. This is not unexpected, because students' understanding about the science is not necessarily linked to their faith or

their attitude towards the biotechnology. For example, an individual with a high level of religious faith might have a good understanding of the technology but still consider its use to be morally unacceptable. For almost every other measure of attitude towards biotechnology, the three scales of religious belief were associated with a statistically significant negative attitude towards the technology, with the single exception being attitude to Genetically Modified Food, which was not statistically significantly correlated with Religiosity.

Stepwise regression analysis indicated that the Christian Orthodoxy scale was positively associated with students' understanding of biotechnology, and it was the only religious belief scale to have a significant positive regression weight on any of the attitudes towards biotechnology scales. This result suggests that, in general, students' religious beliefs are not a good predictor of his or her knowledge about biotechnology, and there is no theoretical basis or statistical evidence in the literature that it should be. However, amongst this cohort of students, there could be a possible link between Christian orthodoxy and understanding of biotechnology.

An individual who scores high on the Christian Orthodoxy, Biblical Literalism, or Religiosity scale is more likely to: hold negative beliefs about the technology, be associated with negative emotions regarding biotechnology, be unaccepting of the inevitability of the technology, hold greater concerns about the use of the technology and be less inclined to buy genetically-modified food products or use medical applications of biotechnology.

The use of stepwise regression analysis allowed the identification of the religious belief scale that was best able to predict a student's attitude towards biotechnology. All three of the religious belief scales were shown to be useful in predicting the different measures of students' attitudes towards biotechnology. The Biblical Literalism scale best explained differences in the cognitive strand; the affective strand was mostly explained by the Christian Orthodoxy scale; and the behaviour strand was split, with Genetically Modified Food being best explained by the Biblical Literalism scale and Medical Intentions by the Religiosity scale.

These results add to the literature that supports the trends found in surveys of the general population, which have suggested that a Christian religious belief, especially fundamentalist beliefs, is negatively correlated with attitudes towards biotechnology

that include GM food (Lesley, Hunt, Fairweather, & Coyle, 2003), stem cell research (Macer et al., 1995), cloning (John Evans, 2002; Weasel & Jensen, 2005), and medical applications (Jordahl, 1993). The findings of this study extend that research to include Australian high school students attending a faith-based school. The identification of a statistically significant association between Christian religious belief and attitudes to biotechnology in this study involving young adults (17 and 18 year-olds) is especially noteworthy because it reveals that the influences of religious thinking and religious ideologies on attitudes towards biotechnology, which have previously only been measured in college-level and adult populations, are also evident at a relatively young age.

Scheitle, (2005) found that, in the United States at least, there was no difference in the optimism about biotechnology on religious grounds amongst a survey of the general population, except for those individuals characterised as fundamentalist, who demonstrated more optimism than the general population. While the names might evoke two different concepts, the items measuring optimism used by Scheitle (2005) were very similar to the measures of inevitability found in the BARBQ. The findings of this study differed greatly by indicating that religious belief was not associated with a positive outlook on the future of biotechnology. Admittedly, Scheitle (2005) himself notes that his results might be specifically linked to American culture and ideology.

This study attempted to measure students' Christian worldview through scales that measured their core beliefs with the Christian Orthodoxy scale, their position on the evangelical (fundamental) versus liberal spectrum of Christianity through the use of the Biblical Literalism scale, and their religious behaviour, along with the importance that they place on their religion, through the Religiosity scale. Correlation and regression analyses suggest that, together, each of these aspects of the Christian worldview plays a role in the development of a student's attitudes towards biotechnology. However, the measure of fundamentalist views, the Biblical Literalism scale, which was identified in the literature as being a key determining factor in understanding attitudes towards cloning and stem cell research, was not observed to have unique explanatory power across the full range of biotechnology attitude measures, although it did provide good explanatory power for Beliefs About Biotechnology and Genetically Modified Food Intentions. It is clear then that while

Christian Orthodoxy, Biblical Literalism, and Religiosity each provide a predictive power in the determination of a student's attitude towards biotechnology, the development of a student's attitude towards biotechnology is far more complex than a simple reflection of their core religious beliefs, the manner in which they interpret Scripture, or even the importance that they place in their religious beliefs.

As suggested by the multicomponent view of attitude development (discussed in Section 2.3.2), the development of an individual's attitude and his or her behaviour are dependent on the combination and interaction of a range of beliefs and assumptions, including, but not limited to, the measures of religious belief used in this study. For this reason, it might not be possible to extract a unique religious belief, perspective, or assumption, which provides explanatory power to a student's attitude towards biotechnology. Furthermore, it is not possible to determine the extent to which the measured levels of Christian worldview, and student attitudes towards biotechnology, are the students' personal reasoned opinions or merely a reflection of the mores of their society. If such an explanatory variable does exist, a different approach towards religious belief could be required to elucidate the underlying suppositions between religious belief and a negative attitude towards biotechnology.

In the search for a better explanation of the association between religious belief and attitudes about biotechnology, one possible pathway could be to examine students' views about God, an approach that has recently been explored by Froese and Bader (2010), with some success. These researchers used two scales to identify what individuals believed about the way that God judges the world and the extent to which God engages in the world. Froese and Bader (2010) suggested that individuals who believed that God was both judgemental and engaged in the world held a distinct view of God, whom they described as an authoritative God. When an individual's perception of God was described as un-engaged with the world and non-judgemental, they were describing a distant God. In a similar fashion, a benevolent God was described as involved in the world but not judgemental, and a critical God was described as judgemental but not involved. This method of classifying an individual's religious belief has proved a useful approach in predicting attitudes towards a number of ethical issues, such as abortion and stem-cell research, as well as attitudes towards science in general.

Those individuals who believe in an authoritative God were more opposed to abortion and stem-cell research and were more critical of the role of science than, in decreasing order of opposition and criticism, believers in a benevolent God, critical God, distant God, or atheists. An authoritative God was also associated with biblical literalism and evangelical (fundamentalist) Christians, and this supports the findings of this research, which has identified a more negative attitude to biotechnology amongst students identifying with a more literal interpretation of the Bible. Whether such an approach to religiosity remains valid for secondary school-aged students, who might have spent little time contemplating the nature of God, remains untested.

### **7.3.3 Concerns About Biotechnology**

Analysis of the data shown in Section 4.10 showed that students who scored high on the religious belief scale tended to be more concerned about specific biotechnology issues than those students with a low level of religious belief. The *BARBQquant* (Concerns scale), the use of technology involving In Vitro Fertilisation (IVF), Genetic Modification of Plants, Animal Cloning, Genetic Modification of Animals, Genetic Modification of Humans, and Reproductive Human Cloning all showed a statistically significant difference between those students with a low level of religious belief and those with a high level of religious belief. From the ethical dilemmas in *BARBQqual*, technology that involved Genetically Modified Food, Therapeutic Cloning, Pre-implantation Genetic Screening and Reproductive Cloning all showed significant differences between these two groups of students.

In earlier studies involving Australian (Dawson & Schibeci, 2003) and non-Australian (Gunter et al., 1998; Kolarova, 2009) secondary students, it has been shown that the acceptance of biotechnology decreases when the technology moves from plants to animals and from animals to humans. The current study supported these findings, demonstrating a similar pattern of concerns.

Of more importance to the current study is the observation that students high on the religious belief scale were, on average, less accepting of all the biotechnologies presented to them than were their less religious peers. In general, the effect size for differences between students with a low level of religious belief and those with a high level of religious belief increased as the technologies moved from plants and bacteria to animals, then humans. This suggests that religious belief might have a

polarising effect, whereby some biotechnologies generate a greater level of concern in the students with a high level of religious belief compared with those students with a low level of religious belief. Once again, the presence of this dissimilarity between the two groups is noteworthy, as it highlights that students accepting a Christian worldview are formulating an opposition to biotechnology at a young age.

The effect sizes for the six technologies for which differences were statistically significant ranged from approximately one-half of a standard deviation (0.56) to three-quarters of a standard deviation (0.89), and can be described as a medium-to-large effects using Cohen's (1988) criteria. To better understand the effect size, the common language effect size statistic (CLES) can be used. This describes the probability that a person from the high level of religious group will have a greater concern about the technology than an individual from the low level of religious belief group if both individuals were selected at random (Coe, 2002). Using this criterion, the smallest effect size for a statistically significant between-group difference occurred for Concerns: IVF, which would have a probability of approximately 65%, while the dilemma Genetically Modified Food, which had the largest effect size with statistically significant differences, would be around 80% probability.

Of the 12 technologies investigated, between-group differences for Genetic Modification of Bacteria and Therapeutic Human Cloning did not have statistically significant differences between the students with high and low levels of religious belief. The genetic modification of bacteria has been taking place for some time and is part of mainstream science and industry; this, in conjunction with the low regard most individuals have for bacteria, could have contributed to the finding of no statistically significant difference between the two groups. Likewise, the high level of concern about reproductive cloning across the population could have contributed to a decreased effect size for this technology.

While the use of therapeutic cloning in humans is considered controversial amongst many Christian groups, no statistically significant differences between students with high level of religious belief and students with low level of religious belief were found in the affective concerns strand of the *BARBQuant*. It is likely that students may not have fully appreciated the significance of this technology, which was

described as ‘cloning of human stem cells for the treatment of sick people’. A full evaluation of the ethical issues involved in this technology necessitates a detailed understanding, not only of the process of cloning, but also of stem cells. This is an understanding that many of the students may not have had. When attitudes towards therapeutic cloning were measured in the ethical dilemmas, a statistically significant difference was observed with a medium effect size. Because the ethical dilemmas placed the technologies within a social context, it is possible that this additional information better equipped students to make ethical decisions. This could explain why a larger effect size was observed whenever the technologies were presented to the students with some context, as found in the biotechnology ethical dilemmas section of the BARBQ.

Given the strong stance of the Catholic Church against IVF, it may be considered unusual that a greater effect size was not seen between the low-religious and high-religious groups for this technology. However, all three schools are Protestant faith-based (although there are both Catholic students and staff in some of the schools), and, in general, Protestants tend to be more accepting of IVF, albeit often with certain constraints. Indeed, upon consideration, the observation of a statistically significant difference between these two groups is interesting given the widespread acceptance of IVF amongst the general population in Australia.

#### **7.3.4 Summary for Research Question 1**

As part of a larger examination of students’ reasoning and attitude regarding biotechnology, the researcher has sought to determine whether or not Christian religious belief was a predictor of attitudes towards biotechnology. The quantitative results presented in Chapter 4, and discussed here, suggest that religious belief is a predictor of attitudes towards biotechnology for students attending a faith-based school, even when the confounding associations between both gender and religious belief and gender and negative attitudes towards biotechnology are considered.

The use of a comprehensive measure of religious belief that incorporated a worldview approach was validated, with the three aspects of a Christian worldview, biblical literalism, religiosity and Christian orthodoxy, all proving useful in predicting a student’s attitude towards biotechnology. And yet, even with a comprehensive measure of Christian worldview, a unique deterministic measure of



biotechnology attitudes could not be identified. As such, this study suggests that alternative approaches to understanding religious worldview need to be explored so that a better understanding can be developed of what it is about a Christian worldview that provides a tendency to reject biotechnology.

This research has been able to specifically show that religious belief is associated with an increase in concerns about biotechnology for a range of specific technologies. This difference between students with a high level of religious belief and those with a low level of religious belief was not limited to technologies that are associated with the well-publicised religious concern recognising the embryo as a full human entity, and are therefore aligned with the abortion debate. Rather, the decreased level of acceptance spanned the spectrum of technologies, suggesting that presuppositions more fundamental to the students' worldview are driving students' concerns about these technologies.

The discussion also highlighted the benefits of providing students with some contextual information about the technology, as this resulted in greater between-group effect sizes, presumably as a result of students being more likely to identify the ethical issues involved in the technology.

## 7.4 FINDINGS FOR RESEARCH QUESTION 2

The second research question asked: Does the acceptance of a Christian belief affect a student's pattern of informal reasoning? To answer this question, a quantitative approach was taken that allowed for the frequency with which the three modes of informal reasoning, rational, intuitive and emotive, was used by students with a high level of religious belief, compared with those students identified as having a low level of religious belief. Before addressing the role of religious belief in informal reasoning, a comparison is made of the patterns of informal reasoning found in this study when compared to earlier research.

### 7.4.1 Comparisons of Patterns of Informal Reasoning with Previous Studies

The frequency with which students utilised the three modes of informal reasoning was substantially different to Sadler and Zeidler's (2005a) study involving American college students and Topçu's (2010) Turkish study, also involving university-level students, who tended to use rational reasoning much more frequently, likely the result of increased age and the process of undertaking tertiary education. The

decreased use of rational reasoning found in the two Australian studies of high school students (Dawson & Venville, 2009; Yap, 2012) more closely resembles the results of this study, which found that intuitive reasoning was the most common of the three modes of informal reasoning, followed by rational informal reasoning, with the least used mode being emotive reasoning. The frequency with which students used emotive reasoning was substantially less than what was found in most other studies (Dawson & Venville, 2009; Sadler & Zeidler, 2005a) but similar to that found by Yap (2012), who also identified emotive reasoning as being the least common mode of informal reasoning used by students.

Few studies exist in which patterns of informal reasoning can be compared, and methodological differences make comparisons between those studies problematic. The research performed by Sadler and Zeidler (2005a), although using the same set of ethical dilemmas, involved older students undertaking tertiary education, and the research of Dawson and Venville (2009) utilised different ethical dilemmas. While Yap (2012) used the same ethical dilemmas as this current study, and was similarly situated in a Christian faith-based school, she used a different method for the coding of students' informal reasoning, adding 'moral reasoning' to Sadler's (2005a) original three modes that consisted of rational, emotive, and intuitive informal reasoning. From an examination of the current literature and the findings of this research, it is clear that actual patterns of informal reasoning are going to vary greatly depending on the cohort of students and the socioscientific issues being examined. While this means that extrapolation of this set of data to other groups and other SSI's may not be appropriate, it is evident that students are not utilising a balanced approach to their informal reasoning. For this reason students would benefit from an educational program that made them more aware of their use of informal reasoning, and develop an appreciation of the need for rational reasoning when making decisions that involve science.

While broad trends concerning the patterns of informal reasoning amongst students in this and other studies may be justified, it is not known what priority the students placed on each of the three modes of informal reasoning when making their final decision about a socioscientific issue, as it has been shown here, and by others (Dawson & Venville, 2009; Sadler & Zeidler, 2005a), that more than one mode is often used when negotiating socioscientific issues. It may be that although the

student uses intuitive reasoning they are basing their decisions about the biotechnology on the rational or emotive aspects of their reasoning. However, it is unlikely that this is the case given the research described in the literature review (Section 2.4.2), which describes how students may be making decisions about an issue first and then coming up with rational arguments to justify their decision (Jonathan Evans, 1996; V. Thompson & Evans, 2012; Wu & Tsai, 2007).

#### **7.4.2 Informal Reasoning and Religious Belief**

While the patterns of informal reasoning do not appear to be consistent across different studies, the relationship between the modes of informal reasoning used by students and their religious beliefs can still provide an insight into the role that Christian belief systems play in students' thinking about biotechnology. The results from this study identified differences in the patterns of reasoning between students who scored low on the Christian Worldview Scale (CWS) and those who scored high on the CWS. Students who scored high on the CWS employed rationalistic and emotive reasoning less often than those with low level of religious belief, as measured by the CWS, and used intuitive reasoning more frequently than their less religious peers. The results examining students' Reasoned Religious Belief Level (RRBL) indicate that students rarely incorporate their religious beliefs as part of their rational reasoning, and it is never included in emotive reasoning. The inclusion of God and religious ideas was mostly observed in relation to intuitive reasoning.

##### **7.4.2.1 Emotive Reasoning**

The absence of any positive reference to religion while using emotive reasoning, and the less frequent use of this mode of reasoning by students measuring high on the CWS, are interesting given the long Christian tradition of care and empathy for the sick and less fortunate. It is often assumed that because of the biblical notions of 'love your neighbour' and 'the Good Samaritan', religiosity would correlate positively with measures of empathy and care. If one assumes that a student who demonstrates a greater degree of empathy would also be more inclined to engage in emotive reasoning, although no such connection was examined in this study, it could be hypothesised that those individuals who recorded a greater level of Christian belief should correspondingly demonstrate a greater reliance on emotive reasoning. This study found no evidence for such a conclusion, with the obvious explanation being a possible misconception that religious belief correlates with measures of

empathy. Evidence was presented in the literature review (Section 2.4.5) for a possible positive correlation between emotive reasoning and religious belief (Francis & Pearson, 1987). It was noted, however, that the individual's attitude and approach to religion is a better predictor of measures of empathy and emotional intelligence than religiosity itself (Duriez, 2004; Watson et al., 1984), and this may provide a possible explanation for the low amount of emotive reasoning amongst those students purporting to follow a Christian worldview. It must also be remembered that the study focused on adolescents on the edge of adulthood and consequently many would be immature in both their general and Christian life experiences. Therefore, as suggested by Hoffman (1975), their capacity for empathy, and hence emotive reasoning, may still be developing.

#### **7.4.2.2 *Rational Reasoning***

Upon examination of the frequency of rational reasoning, it is clear that many students, including those scoring high on the CWS, are using rational modes of reasoning. However, although the students with high and low levels of religious belief used a similar number of rational comments, it is clear that fewer students with a high level of religious belief utilised that mode of reasoning. The findings of Chapter 7 also show that few have incorporated into their informal reasoning rational arguments that include faith-based reasoning. The possibility of this result was discussed in Section 2.4.5 of the literature review, although the evidence was somewhat tentative. One factor that could have contributed to this result is that students do not have a good understanding of what their faith is, and are only able to reflect the ideas of their faith community without having an understanding of why they hold that position. While this idea is subjective and would require further study, it would explain the greater reliance on intuitive reasoning over rational reasoning; however, other factors are likely to also be involved. Students may also have had limited exposure in exploring how belief systems are used to develop resolutions to ethical issues, or they may simply be unable to articulate their ideas about the role that faith plays in their decision-making. Whatever the reason, these results demonstrate that if a student does incorporate their religious beliefs into their decision-making process, it is more likely to involve intuitive reasoning over a rational approach that identifies relevant Christian or faith principles.

#### **7.4.2.3 *Intuitive Reasoning***

It has already been noted that students who scored higher on the religious belief scale tended to include more intuitive reasoning and less comments involving rational reasoning than their less religious peers. These differences are consistent with the findings of Shenhav et al. (2012) and others (Aarnio & Lindeman, 2007), who demonstrated that, at least in the adult population, the use of intuitive thinking styles over reflective ones were associated with an increased belief in God. Shenhav et al. (2012) suggest two possible, although not mutually exclusive, explanations for this observation. Firstly, they suggest that an individual who is more inclined to use intuitive reasoning may be more attracted to a belief in God because it supports other intuitive explanations, and secondly, an intuitive belief in God may support the use of intuitive reasoning in other situations. The results of this study could also be explained in both of these terms. A stronger belief in God, as indicated by the CWS, may foster the application of intuitive reasoning in other situations such as concerns about biotechnology. It may also be the case that those students who use intuitive reasoning are more likely to have a belief in God and therefore score higher on the CWS. If either, or both are true, then the observation of low amounts of rational reasoning amongst students scoring high in the CWS can be easily explained, along with the greater reliance on intuitive reasoning.

#### **7.4.3 Summary for Research Question 2**

The frequency with which students used the modes of informal reasoning was within the scope of previous research findings and aligned most closely with research from a similar cohort of students. The low levels of emotive reasoning amongst believers appeared to be inconsistent with the ideologies of the Christian faith, but were broadly in agreement with the limited research that has been done in this field. Rational reasoning was underutilised by all students, but more so by students with a high level of Christian belief, which is in agreement with the limited research that exists in this area of study. Even when utilising a rational mode of reasoning, these students rarely made a rational connection between the biotechnology issues and their faith. The findings of this study also support evidence that is suggestive of an increased reliance on intuitive reasoning by students with a high level of religious belief, although the mechanism for this trend remains uncertain.

## 7.6 FINDINGS FOR RESEARCH QUESTION 3

The third research question addressed in this study asked: How are students' religious beliefs incorporated into their informal reasoning about biotechnology? This section will draw from the analysis of both the qualitative and quantitative data that is pertinent to this research question, and which was presented in Chapter 6. This section will discuss the gap between students' level of religious belief and their use of religious principles and ideas, as part of their reasoning about biotechnology issues. From this analysis alone a simple answer to the third research question would be, for most students, 'not very often and not very well'. However, the student questionnaire allowed for a deeper exploration of this question by examining the ethical arguments or ideas used by the students when responding to the four ethical dilemmas.

### 7.6.1 Frequency of Religious Ideas in Student Reasoning

Analysis of the students' responses presented in Section 6.8 has identified that considerably fewer students use religious ideas in their reasoning than were identified as measuring high on the CWS. Even when they do incorporate religious ideas into their reasoning, they rarely incorporate rational reasoning involving faith-based principles. While this low level of engagement between a student's worldview and their reasoning may be disheartening for some educators, Reiss (2008, p. 899) highlights the fact that although they may not do it particularly well, "the evidence suggests that students are able to reason about ethical matters. This is a considerable achievement on the part of the students." The data presented in this research supports Reiss's comments, for although the students often failed to provide a clear connection between their Christian worldview and their moral judgements, nevertheless 45% of the 145 students were able to provide at least some rational modes of informal reasoning, which indicates at least some degree of engagement in ethical thinking. Nor is this lack of clarity between the students' worldview and their informal reasoning necessarily surprising. As was noted in the literature review (Section 2.5.1), moral values and attitudes can ultimately be traced back to an individual's worldview, therefore it might be expected that students with Christian worldviews would incorporate their beliefs into their moral judgements. However, it was also made clear in the literature review that most individuals do not stop to closely examine their worldview, which may direct the decisions and attitudes of an

individual without the student's conscious awareness of the fact. It is therefore expecting much of a young adult to make the connections between the sometimes-abstract concepts of their faith, and the presupposition of their Christian worldview, to a hypothetical ethical dilemma. Although the expectation that students will be able to provide moral arguments that are able to offer clarity to their worldview may remain unmet, the process of worldview development that was described in Section 2.5.2.4 of the literature review, and which involves engaging with socioscientific issues, provides an opportunity for the examination and transformation of worldviews. It is this, Cobern (1997) has suggested, that should be one of the primary goals of education.

While previous research has suggested that religious-based reasoning may be context dependent (Yap, 2012), this was not evident in the present study, with only genetic screening showing a small increase in the amount of religious reasoning used.

### **7.6.2 Ethical Arguments**

After a detailed review of the students' written responses and the interview data, 12 types of ethical arguments were identified that represented key concepts used by students in their reasoning. The 12 ethical arguments were: 'health benefits', 'social justice', 'health concerns', 'not natural', 'playing god', 'God is Creator', 'God's will', 'human embryo', 'uniqueness', 'slippery slope', 'religion limits science' and 'science disregards faith'. The fact that these ethical arguments, which mirror the concerns of adult religious thinkers and Christian religious institutions, can be identified in young adults who have not yet completed their secondary education is further evidence that the formation of attitudes about biotechnology, along with the beliefs and arguments associated with those attitudes, is often well developed by the time students complete their high school education. The extent to which these attitudes and beliefs will remain throughout tertiary education and adult life remains unknown; however, it is known that many, possibly as much as 40%, will leave their faith during the years immediately following their secondary education (Dudley, 1999; Gane, 2012).

The rejection of God as the ultimate source of authority was discussed in the literature review (Section 2.6.1) as being a possible source of religious concern about biotechnology. Although it was not the only reason that individuals rejected

biotechnology, it offers a useful interpretive framework through which to view the ethical arguments that were gleaned from the analysis of student responses. These ethical arguments can be further put into context with a comparison of the three major concerns about biotechnology that have been put forward by religious groups. These include concerns about justice in the distribution of the risks and benefits of biotechnology, concerns about the perceived tendency towards materialistic reductionism or commodification of the intrinsic value of human life, and concerns about the use of prenatal genetic testing and its relationship to abortion. A full description of these concerns is outlined in Section 2.6 of the literature review.

Statistical analysis of the types of ethical arguments identified in Section 6.5 and Section 6.6 provided additional information from which to understand students' reasoning when they used these ethical arguments. Of the ethical arguments with statistically significant differences between the students using the argument and those not using the argument, reasoning that was associated with support for the use of biotechnology included, 'health benefits', 'social justice' and 'religion limits science'. Reasoning that was used more often when rejecting the use of biotechnology included 'health concerns', 'not natural', 'playing God', 'God is Creator', and 'God's will'. The large effect sizes calculated for these ethical arguments validate the importance of these ethical arguments in students' attitudes towards biotechnology.

Of the ethical arguments with statistically significant differences between the students using the ethical argument and the students not using the ethical argument, the ethical arguments measuring higher on the Christian Worldview Scale (CWS) included 'not natural', 'God is Creator' and 'God's will'. The moderate effect size for 'not natural' and the large effect sizes calculated for 'God is Creator' and 'God's will' validates the significance of these ethical arguments for students with a high level of Christian religious belief when they are presenting arguments about biotechnology. Students scoring lower on average than their peers on the CWS used none of the ethical arguments more frequently than the more religious students.

The statistical analysis of the 12 ethical arguments provided some insight into the biotechnology attitudes and religious belief of the students using a particular ethical argument, however, the approach has a number of limitations. A statistically



significant difference indicated that there is a difference between students who used a particular ethical argument and those who did not, in that they would be more likely to have a higher or lower score in the CATBS or the CWS, depending on which group they are in. This tells us something about the students who used the ethical argument compared to those that did not, however, it in no way suggests that any particular ethical argument holds more ethical weight in an individual's ethical reasoning. Also, just because ethical arguments related to the human embryo were not statistically significant for differences in the CWS, while 'God is creator' was, does not mean that the latter argument is more convincing for the student than the other. Indeed, arguments associated in any way to the abortion issue often trump other considerations, as was observed in the responses made by students that were classified under the slippery slope ethical argument and discussed in Section 6.3.3. A failure to observe a significant result could be the result of two independent factors. It could be that no significant difference exists between the two groups, and this is likely to be the case for at least some of the ethical arguments here, or the sample size is too small to detect more subtle differences that may exist.

#### ***7.6.2.1 Health Benefits and Health Concerns***

Students who used the ethical argument of 'health benefits' were associated with a higher level of acceptance towards biotechnology. Conversely, those who used the ethical arguments of 'health concerns' in their reasoning scored, on average, lower on the Combined Attitude Towards Biotechnology Scale (CATBS). As explained in the literature review (Section 2.6.2), the health benefits of biotechnology is one line of ethical reasoning that is supported by many religious groups. However, it would appear from this study that a student from a Christian worldview is no more or less likely to use the health benefits or concerns arguments when reasoning about socioscientific issues than their peers. These arguments are hardly unique to a religious worldview, so the result is not unexpected.

#### ***7.6.2.2 Social Justice***

Students using the ideas associated with social justice were more positive about the use of biotechnology, viewing it as a way to provide support for the underprivileged. The use of the 'social justice' ethical argument showed no statistically significant differences when comparing the averages of students' scores on the Christian Worldview Scale (CWS), although it was indicative of support for biotechnology. It

is expected that this support is a reflection of the context of the dilemmas as most of the social justice comments came from the Genetically Modified Food dilemma where students highlighted biotechnology's ability to provide food resources for third-world countries. The use of this ethical argument for the other three dilemmas was more negative towards biotechnology. Social justice issues are considered important for many Christians, as was highlighted in Section 2.6.2. Justice in the distribution of the risks and benefits of biotechnology was one of the main concerns of religious organisations regarding biotechnology. It was also the case that the widespread support of biotechnology, found in reports from religious organisations, could be traced back to the possibilities of biotechnology providing new ways to relieve suffering and increase food production. It has previously been noted in this study that the more religious students did not demonstrate any more emotive informal reasoning than their less religious peers. The lack of a distinction in the measured level of religious belief between students using social justice ethical arguments and those who did not further emphasises the point that, at least for this cohort of adolescents, the use of reasoning based on care, empathy and social justice is not an indicator of an individual's level of religious belief.

#### **7.6.2.3 *Not Natural***

Students who used the ethical argument 'not natural' in their reasoning scored, on average, lower on the Combined Attitude Towards Biotechnology Scale (CATBS) and higher on the Christian Worldview Scale (CWS). Two reasons can be suggested for the differences between students who used the 'not natural' and those who did not. This phrase can be considered an example of intuitive reasoning and therefore its more frequent use by students with a higher religious belief may reflect the tendency for those students to utilise intuitive reasoning. While this may hold true, it seems more likely that the ethical argument 'not natural' is aligned with a Christian view of 'God is Creator', and what is natural is that which is God ordained.

#### **7.6.2.4 *Playing God***

Students who made reference to the ethical argument 'playing God', scored, on average, lower on the CATBS. This provides further evidence that religious beliefs are influential in determining the negative attitude towards biotechnology. Furthermore, it points to a view that the faith-based reason for rejecting the biotechnology is because the technology is seen as usurping the authority of God in

his creative domain, along with God's authority to know and direct the future, as indicated by the association of 'playing God' with 'God is Creator' and 'God's will'. However, while appeals to 'playing God' were used when reasoning against the use of biotechnology, this may have little to do with an individual's theological reasoning. The reference to the ethical argument 'playing God' showed no statistically significant difference in the students' level of Christian belief. Exactly what is meant by the use of this phrase is not always clear; however, the findings of Section 6.4 tend to suggest that it is a reference that humans in general, or scientists in particular, are making decisions about life issues that go beyond what they feel is the authority and dominion of mankind.

The use of the term 'playing God' has been discussed in depth in the literature (Barab et al., 2010; Chadwick, 2009; Erde, 1989; Ryan, 1995; Verhey, 1995; Weasel & Jensen, 2005) and summarised in Section 2.6.1.2. While it was clear that the phrase 'playing God' was not necessarily used in the religious sense and may simply be a place-holder for 'not natural', a number of authors have suggested that, for some individuals at least, the phrase does have significant theological meaning (Dragojlovic & Einsiedel, 2013; Gaskell & Bauer, 2001; Polkinghorne, 2000). The research presented in this study suggested that the term does have a religious or philosophical meaning for at least some of the students using it. Analysis of the data presented in Chapter 6 suggests that the underlying concerns behind this phrase reflect the different philosophical positions, albeit in a much less articulated way, of prominent ethical thinkers such as Chadwick (1989), Verhey (1995) and others, who also refer to the concept of rejecting the authority or power of God. Chadwick used the theological term *omnipotence*, and this is often the essence behind the phrase 'playing God' when used by the students. This was, however, not always the case, and it was evident that, for some students, the term had little or no theological significance. Although for this cohort of students the ethical argument 'playing God' is not statistically linked to a religious worldview, it is evident from the qualitative results presented in Section 6.4 that for some individuals this term does have religious significance.

#### **7.6.2.5 *God is Creator and God's Will***

The two ethical arguments of 'God is Creator' and 'God's will' are both manifestations of the belief that God has ultimate authority over all life. The ethical

argument ‘God is Creator’ is an argument suggesting that as the creator of life, God necessarily has authority over His creation. Furthermore, this authority extends to knowing what is best for His creation. Therefore, anything He creates, which, for Fundamentalist Christians would be all living things, is necessarily already the best it can be, so any effort to change God’s creation is also a challenge to that authority. ‘God’s will’ is a reference to God’s authority over the events in an individual’s life, including the authority over life and death. Technology that relieves God of some of His authority is a challenge to this position. Given that only the domain over which God is exercising dominion separates these ethical arguments, the two will be discussed together.

As was expected, those students who included the arguments ‘God’s will’ and ‘God is Creator’ scored, on average, higher on the CWS. Although these two ideas are unique, both can be viewed as an incarnation of the concepts and emotions that were typically expressed as ‘playing God’. It is in these two concepts that the religious dimension of the phrase ‘playing God’ is observed. While a non-religious individual may use the phrase ‘playing God’, as was observed by some students in the questionnaire, making reference to ‘God’s will’, or ‘God is Creator’, infers a more personal belief in a God.

Use of the ethical argument ‘God’s will’, which was sometimes phrased by students as ‘God’s plan’, is commonly used by religious individuals as a means of coping with stressful life situations such as the breakdown of a relationship or the death of a loved one (Pargament, Koenig, & Perez, 2000). Pargament et al. (2000) identified that this coping mechanism is an attempt by individuals to redefine the stressor as having a spiritual benefit. In this study, students using the ‘God’s will’ argument typically justified the situation with the idea that something good would come out of the situation, although the concept of spiritual development was never explicitly mentioned. It is plausible that the ‘God’s will’ argument, as described in Section 6.3.4, is a part of the students’ attempts to make sense of why bad things happen.

The two ethical arguments, ‘God’s will’ and ‘God is Creator’, are statistically linked to a religious worldview. Students who used one of these ethical arguments had, on average, a higher level of religious belief. It was shown in Chapter 4 that technologies that involve Therapeutic Human Cloning, Animal Cloning, and Genetic

Modification of Animals were divisive, in that these were the three technologies where students with low level of religious belief, who generally supported their use, differed from those students with a high level of religious belief, who did not support the technologies. A reflection on the two ethical arguments ‘God’s will’ and ‘God is Creator’, provides some insight into the reasons for this difference between the two groups. Indeed, it may partially explain the lower level of acceptance of biotechnology in general for students with a high level of religious belief. In this study, students with a high level of religious belief were typically associated with a literal interpretation of the Bible, which is associated with a fundamentalist Christian worldview, and therefore these students incorporated into their ethical reasoning an authoritative view of God. As discussed in the literature review (Section 2.6.3), Fundamentalist Christians hold to a view of perfect divine creation and a God who is active in everyday affairs of humans. There is therefore very little theological room for a God who allows humans to be co-creators with Him, or for technologies that interfere with the plans that God has for an individual. This thinking is reflected in the students’ responses, which often emphasised the idea that God created humans and animals in a certain way, and He allows, or even determines, that certain events take place. This is a clear rejection of the concept of co-creators, adopted by more liberal Christians, and for these students biotechnology provides a method whereby the authority of the God who created, and the God who ordains, can be circumvented. Many appear to reject biotechnology because of it.

Froese and Bader (2010) studied the views of people who hold to an authoritarian view of God. From this framework, those who hold an authoritarian view of God describe God as being both judgemental, handing out punishment for those who do wrong, and also engaged in the world, that is, a God who intervenes in the daily lives of individuals. These two researchers have demonstrated that individuals (American adults) who believe in an authoritarian view of God are more likely to be opposed to a number of morality issues, including abortion and stem cell research, and feel that such issues are always wrong. Froese and Bader (2010) also demonstrated that Christians who identify with an authoritative God believe that scientists are usurping God’s authority, and this is one of the driving factors in these individuals rejecting aspects of biotechnology. It may be that an individual’s beliefs about the nature of God are more reflective of a willingness, or unwillingness, to accept biotechnology.

It is interesting to note that the ethical arguments of ‘uniqueness’, and those technologies involving the ‘human embryo’, did not show statistically significant differences in attitudes towards biotechnology. A possible explanation for this is that these are the ethical arguments that portray a more personal nature of God, as One who is interested in the uniqueness of individuals, including the potential individual an embryo could grow into; as such, these ethical arguments may be associated with a more moderate view of biotechnology and a more liberal view of Christianity. More research would need to be done to explore this idea, as this study was not designed to answer this specific question.

#### **7.6.2.6 *Human Embryo***

As has been noted in the literature review (Section 2.6.1.1), any technology that is associated with human embryos can be problematic for many Christians. Religious groups specifically address this issue, as they are concerned about the intrinsic value of human life as well as the consequences of some technologies, such as pre-implantation genetic diagnosis (PGS), resulting in abortion. Arguments that made reference to the human embryo were used by 25 (17%) students, a figure that appears low when it is considered that this issue is one of the more significant concerns amongst religious groups. One possible reason for this is that the dilemmas presented in the study did not specifically mention that the embryos would likely be destroyed by the technology. Students therefore required some basic additional knowledge of the process to make these connections. Another reason for the infrequent use of this ethical argument may be that a large number of students did not hold to the traditional Christian view that human life begins at conception. While it was clear from the interviews that some of the Christian students did not hold this view, and in fact a range of interpretations were presented, similar to the diversification that exists amongst Christians in general, it seems unlikely that the cohort of religious students, which appears to be aligned with fundamentalist Christian worldviews in other areas, would differ so significantly in their beliefs about the moral status of the human embryo.

#### **7.6.2.7 *Uniqueness***

The ethical argument ‘uniqueness’ may also come out of the view of God as the ultimate authority, in that it was often used as an extension of the idea of ‘God is Creator’. A human life was considered a gift from God and therefore any attempt to

change that gift, such as altering the genetic makeup of a child, was considered by some of the students to be both ungrateful and, once again, a rejection of God's authority. The students also echo the concerns voiced by religious groups when using this argument, as they are reflecting on the intrinsic value of human life. The idea of uniqueness was used by 24 (16%) of the students and was not restricted to students with high level of religious belief. There may therefore be a more fundamental presupposition, one that traverses the religious worldview divide, and that may provide a better explanation as to the origins of this ethical argument.

#### **7.6.2.8 *Slippery Slope***

The ethical argument of a slippery slope refers to the idea that a technology is morally wrong because the consequences result in an increased likelihood of actions that would be considered ethically dubious. This is not a uniquely religious argument; however, it was used here, and is used elsewhere (Lamb, 2003), to refer to ethical situations where the consequential action is wrong because of religious ideology. This argument was not frequently used by students, with only six (4%) of them using it, but when they did, students followed similar arguments to those of ethicists, as discussed in Section 2.6.1.3, in that they highlighted concerns associated with abortion resulting from treatments that utilised IVF and therapeutic cloning.

#### **7.6.2.9 *Religion and Science***

Those students who included the argument that 'religion limits science' scored higher on average in the CATBS, indicating that these students are more supportive of biotechnology. This supports the findings elsewhere in this thesis that suggest scoring low in the Christian Worldview Scale often results in students being more accepting of biotechnology. Indeed, as was noted previously in Section 6.3.1, this ethical argument is typified by a rationale that suggests that religion is preventing the necessary progress of biotechnology. Although differences were statistically significant, the number of students who used this argument was very low. Likewise, the number of students using the argument 'science disregards faith' was also low, and therefore caution needs to be taken in the interpretation of these results. The perceived conflict between science and religion is likely the result of conflicting sources of authority. While science has its own methodology for determining truth, Fundamentalist Christians look to the Bible for their explanation of the world and the

resulting conflict was observed in the student comments when one side failed to accept the epistemology of the other.

### **7.6.3 Summary of Discussion Regarding Ethical Arguments**

When students are confronted with socioscientific issues, they are able to appreciate the fact that these are complex issues and they draw upon their own worldview and experiences as they attempt to reason through each of the issues. For many of the students whose worldview is associated with a Christian religious belief, it appears that they have difficulty following through, in a rational manner, how the ideology of their Christian belief system flows into their decisions about socioscientific issues. Despite this difficulty, this research was able to show that four of the twelve ethical arguments identified in the students' responses, ('playing God', 'God is Creator' 'God's will', and 'religion limits science'), provided statistically significant differences between students' level of religious belief and their attitude towards biotechnology. This allowed for additional insight into how students incorporate their religious views into their reasoning about socioscientific issues.

## **7.7 OVERALL DISCUSSION OF RESEARCH FINDINGS**

This chapter discussed the relationship between a religious worldview and students' attitudes towards biotechnology and, in doing so, presented clear evidence suggesting that an increase in the level of religious belief is a predictor of negative attitudes towards biotechnology. In addition, it was discussed how the patterns of informal reasoning differed between the two groups defined by their acceptance or rejection of a Christian worldview. Finally, the nature and frequency of the more common arguments used by the students was explored.

What this research was unable to determine was the extent to which the students were merely reflecting the mores of their society, rather than constructing their own opinions about the technologies. Indeed, the observation that students were generally unable to identify a religious foundation to their attitudes, along with their heavy reliance on intuitive informal reasoning, lends credence to this interpretation of the data.

Woven throughout the findings of the three research questions is the notion of authority, specifically the role of God as the authoritative identity over nature, human lives and the revelation of truth. In the first research question, it was shown that



belief in biblical literalism, a position that suggests that the Bible is a dictatum of God, and therefore the final authority of science and history, provided a significant contribution in predicting a student's attitude towards biotechnology. Therefore, it could be suggested that the question of which has more authority in determining the truth about the natural order, religion or science is important in understanding student attitudes towards biotechnology. Evidence relevant to the second research question showed that students with a high level of religious belief had a greater reliance on intuitive reasoning and a lower use of rational reasoning, suggesting that they could be more likely to accept the authority of church leaders without personally addressing the issues concerned. For the third research question, many of the ideas used by the students in their reasoning were grounded in issues of authority. The two religion-versus-science ethical arguments, 'religion limits science' and 'science disregards faith', presented the conflicting authorities in the determination of truth and, when students complained that the scientists were 'playing God', they were often objecting to the interference by society with Gods' authority. Likewise, the ethical arguments of 'God's will' and 'God is Creator' were objections to the perceived authority that God holds over the lives of individuals and the natural world.

## 7.8 SUMMARY OF CHAPTER

This chapter has provided an in-depth discussion of the results previously presented in the fourth, fifth and sixth chapters. It has discussed the evidence, presented in Chapter 4, which demonstrated that a Christian worldview is a predictor of negative attitudes towards biotechnology. It also discussed the evidence presented in Chapter 5, which suggests that students with a Christian worldview tend to use different patterns of informal reasoning than their less religious peers. This chapter has also discussed the results presented in Chapter 6, which included the frequency with which students' religious beliefs were incorporated into their informal reasoning about biotechnology, and the ethical arguments that were used in that reasoning. Finally, this chapter has provided a general discussion of the results, and identified the issue of authority as being an overarching factor in determining students' attitudes towards biotechnology. The next chapter provides a summary of the research and its findings, highlight the limitations and implications of the study, and offer suggestions for future research.

## **Chapter 8**

### **CONCLUSION**

#### **8.1 INTRODUCTION**

Chapter 8, the final chapter of this thesis, provides an overview of the research and its findings. After an introduction outlining the goals and context of the study, a summary of the research findings is provided, grouped according to the three research questions, and this is proceeded by a description of the distinctive contributions made by this study. The chapter then continues with three further sections, one describing the limitations of the study, another providing a description of the practical implications of the findings, and a final section offering recommendations for future research and some concluding remarks.

A trend towards the use of controversial topics in science education over the last decade has been driven, at least in part, by a desire to develop a curriculum that is relevant and engaging for students. The socioscientific issue movement, in which this study is grounded, has also incorporated the use of controversial issues in science to further these aims. In addition, the socioscientific issue movement recognises the importance of the cultural context within which these issues are addressed and their value in the development of ethical thinking. The specific inclusion of biotechnological issues in the Victorian Certificate of Education (VCE) Biology study design (Learner, 2012) and the content of the Australian National Curriculum (ACARA, n.d.), along with key objectives of the Australian National Curriculum, which call for the development of ethical reasoning and decision-making, have precipitated the need to develop a deeper understanding of the culturally distinct concerns and reasoning about biotechnological issues amongst Australian high school students. This study identified that the cultural differences associated with Christian worldviews, and the impact this has on the attitudes towards biotechnology held by students attending a faith-based Christian high school, have not been adequately explored in the literature. This study therefore sought to provide a better understanding of the role that religious beliefs play in determining the attitudes and informal reasoning of students from an Australian faith-based school and, to this end, collected data from 177 senior students (years 11 and 12) across three Australian (Victorian) secondary schools that were part of a single faith-based education system.

A mixed-methods approach to the research problem involved in the collection and analysis of data from a questionnaire that included the options of closed and extended responses, as well as a number of focus group interviews. Using both qualitative and quantitative data-analysis techniques, the researcher explored the role of religious belief as a predictor of student attitudes towards biotechnology, the influence that the acceptance of a Christian belief system can have on students' patterns of informal reasoning, and an understanding of how a students' religious beliefs are incorporated into their reasoning about biotechnology. This study presents some of the first Australian data available concerning the attitudes and reasoning towards biotechnology of students from a Christian worldview, and compares them with students who do not accept a Christian worldview perspective.

## 8.2 SUMMARY OF RESEARCH FINDINGS

### 8.2.1 Research Question 1

The first research question was: How does religious belief act as a predictor of attitudes towards biotechnology? The key findings of Research Question 1 were:

1. Students scoring low on the Christian Worldview Scale (CWS) as well as students scoring high on the CWS were identified amongst the participants attending the faith-based schools involved in this study.
2. For both male and female students, a higher level of religious belief is associated with a decrease in students' attitude towards biotechnology.
3. Christian orthodoxy, biblical literalism and religiosity all provide predictive power for determining students' general attitudes towards biotechnology and the extent of their agreement with the applications of biotechnology.
4. Students with a high level of religious belief are more concerned than their less religious peers about the technologies consisting of: IVF; genetic modification of plants; animal cloning; genetic modification of animals; genetic modification of humans; reproductive cloning; dilemmas involving GM food; dilemmas involving therapeutic cloning; dilemmas involving genetic screening; and dilemmas involving reproductive cloning.
5. Students form attitudes to biotechnology at a relatively young age, and the association between religious belief and decreased acceptance of biotechnology is observable in high school students.
6. The trend, observed by other researchers, that students are more concerned

about biotechnology issues involving animals and humans than they are about applications of biotechnology that involve bacteria or plants was confirmed.

### **8.2.2 Research Question 2**

The second research question was: Does the acceptance of a Christian belief affect students' patterns of informal reasoning? The key findings of Research Question 2 were:

1. High school students in this faith-based school system used patterns of informal reasoning that were comparable to two other studies involving Australian secondary students, including a variation in the patterns of informal reasoning, depending on the issue that was being addressed.
2. There is preliminary evidence demonstrating that the patterns of informal reasoning by students with a high level of religious belief differ from those with a low level of religious belief.
3. Students with a Christian worldview use more intuitive reasoning and less emotive and rational reasoning than their peers who do not identify with a Christian worldview.

### **8.2.3 Research Question 3**

The third research question was: How are students' religious beliefs incorporated into their informal reasoning about biotechnology? The key findings of Research Question 3 were:

1. Most students provided few arguments for their position on specific biotechnology that were grounded in their religious worldview. Only rarely did they incorporate religious principles or ideas into their reasoning.
2. When religious ideologies were incorporated into students' arguments they included a diversity of Christian views, which mirrored the diversity found amongst adult populations.
3. Twelve ethical arguments were identified as being used by students when justifying their position on biotechnological issues. These were: 'health benefits', 'social justice', 'health concerns', 'not natural', 'playing god', 'God is Creator', 'God's will', 'human embryo', 'uniqueness', 'slippery slope', 'religion limits science' and 'science disregards faith'.
4. The argument most commonly used by students was 'playing God' and, in

contradiction to the suggestions of some researchers, this was frequently used with a religious meaning that suggested biotechnology gave humans an inappropriate power over creation, life and death that ought to be the exclusive domain of God.

5. The use of an ethical argument was dependent on which gene technology was under examination.
6. Use of the ethical arguments ‘health concerns’, ‘not natural’, ‘playing God’, ‘God is Creator’, ‘Gods will’, and ‘religion limits science’ was statistically linked with negative attitudes towards biotechnology.
7. Use of the ethical arguments ‘health benefits’, ‘social justice’ and ‘religion limits science’ was statistically linked to support for biotechnology.
8. Use of ethical arguments involving ‘not natural’, ‘God is creator’, and ‘God’s will’ was statistically linked to a Christian worldview.

### 8.3 DISTINCTIVE CONTRIBUTION OF THE STUDY

This study has been placed within the contextual framework of the socioscientific issues movement. As discussed in Section 2.2.1 of the literature review, fundamental to the socioscientific movement is the promotion of personal cognitive and moral development that takes seriously the cultural beliefs and life experiences of the individual. While much has been written on the importance of cultural issues to the SSI movement (Levinson, 2006; Vellom & Anderson, 1999; Zeidler et al., 2005), very few studies have examined students’ responses to socioscientific issues through the lens of a cultural identity, and this is the first study to do so from the perspective of a Christian worldview. Even outside of the SSI framework, very few studies have set out to specifically measure the influence of religion on attitudes towards biotechnology, and none have done so with high school-aged students.

This research has shown that, even at this young age, a higher level of religious belief is associated with less positive students’ attitudes towards biotechnology, and this is the case for both male and female students. In reaching this conclusion, this study has used a detailed measure of attitude towards biotechnology, that is grounded in attitudinal theory and that encompassed a wide range of biotechnologies. A comprehensive measure of biotechnology attitudes is lacking in many studies that attempted to gauge public perception of these issues, with many studies using only a few questions to measure attitudes. This study also recognised the complexity of

religious belief, and more fully measured the Christian worldview of an individual by taking separate measures of religious behaviour and importance (religiosity), Christian orthodoxy, and scriptural literalism. Through the use of these detailed scales, this research has been able to show that Christian orthodoxy, biblical literalism and religiosity all provide a predictive power for determining students' general attitudes towards biotechnology and the extent that they agreed with the applications of biotechnology involving genetically modified food, pre-implantation genetic screening, therapeutic cloning, and reproductive cloning. This research also presents the first evidence from a single study that individuals with a strong Christian belief are more concerned than their less religious peers about a broad range of biotechnologies, including IVF, genetic modification of plants, GM food, genetic modification of animals, genetic modification of humans, animal cloning, therapeutic cloning, reproductive cloning, and genetic screening. It also represents the first study involving Australian high school students in identifying decreased acceptance by Christian religious students of any biotechnological issues.

Classroom discourse is an ongoing field of inquiry within the SSI movement and yet few studies have explored patterns of informal reasoning from a cultural perspective, and none have attempted to compare students' informal reasoning from the distinct cultural differences of a religious worldview and a non-religious worldview. The research presented here represents the largest study to date that measures patterns of informal reasoning using biotechnology issues, and the first to compare the informal reasoning of students with a relatively low level of religious belief with those of a high level of religious belief. This research also provides the first direct evidence suggesting that students who identify with a Christian worldview use more intuitive reasoning and less emotive and rational reasoning than their peers who do not identify with the Christian worldview.

Through the collection of extensive data in the form of students' extended written responses and interviews, this study has identified the arguments used by students to justify their opinions about biotechnological issues. With a focus on cultural perspectives, this research has described the religious concerns of students about modern biotechnology and identified a gap in many of the students' abilities to make connections between their worldview and their reasoning about socioscientific issues. Through this research, the ethical arguments of 'Science and Religion', 'playing

God', 'slippery slopes', 'God's will', the moral state of the 'human embryo', 'God is Creator', and the 'uniqueness of individuals' have been identified. While these ethical arguments are consistent with the ideas presented by theologians and official religious organisations, this study represents the first of its kind to identify these ethical arguments in the reasoning of high school students.

#### 8.4 LIMITATIONS OF STUDY

This study adopted a mixed-methods approach to the research design in an effort to reduce any limitations to the study. Quantitative techniques were used to understand trends in the data and make comparisons between students with a low level of religious belief and those with a high level of religious belief. One criticism of quantitative attitudinal studies is that they narrow the range of responses based on the researcher's perspective and therefore limit their usefulness as a data source (Kaya, Yager, & Dogan, 2009; Osborne, Simon, & Collins, 2003; Piburn & Baker, 1993). To counteract this concern, a triangulation of methods was used in this study. This was achieved through the use of qualitative methods, which were employed to gain a deeper understanding of students' reasoning processes and conclusions. Used together, quantitative and qualitative techniques allowed a richer understanding of the role that a student's Christian worldview plays in the formation of his/her attitudes towards biotechnology.

The major weaknesses of this study involved the sample size and the makeup of the sample. While the number of participants for the qualitative component of the study was comparable to, and often larger than, the number in similar studies, the statistical rigours of a quantitative analysis demand a much higher sample size than that of qualitative studies. The relatively small sample size for the quantitative part of this research represents a major limitation of the experimental design.

All of the students participating in the research attended one of three schools that were associated with the same faith-based educational institution. These schools actively promote a Christian philosophy and teach Christian doctrine. While students who attend the schools come from a range of religious backgrounds, including some who reject any notion of a God, there were a far greater number of students who were sympathetic to a Christian worldview than students who were not. Furthermore, the schools come out of a fundamentalist Christian tradition and therefore represent,

at least at an administrative level, a relatively narrow perspective of the Christian worldview. This bias towards a Christian worldview resulted in a significantly smaller sample of students identified as having a relatively low level of Christian belief compared to those with a high level of Christian belief. Such a disproportionate sample size between these groups is another limitation of the study. To determine the low level of religious belief subset, the sample was divided in such a way so as to limit that group to students who, on average, disagreed with the core principles of the Christian faith. Because this research only looked at students attending a faith-based school, and the necessity of including in the low level of religious belief sample students who might have partially agreed with some religious ideas, it is appropriate to refer to those students scoring low on the Christian Worldview Scale (CWS) as having a *relatively* low level of religious belief.

Free of the limits of time and resources, data would have been collected from a range of secondary school institutions, including those that operate from a secular ideology, so that a greater level of generalisability could have been obtained. In its current form, this study provided a detailed description of students' attitudes and reasoning about biotechnology from the perspective of a faith-based institution. As with much research conducted within a naturalistic setting, it is problematic to generalise beyond the context from which the results emerged. The inherent difficulties associated with generalisation of this type of research have been observed in the comparison of this study with other research involving the frequency of rational, emotive and intuitive informal reasoning. While this is due in part to methodological differences, it is also the result of the contextual differences associated with the various educational settings studied, and highlights the difficulties involved in the transferability of research in this field. To aid in the transferability of this study, detailed descriptions of the organisation of the study, school context and methods of data collection and analysis have been provided, as suggested by Lincoln and Guba (1985), to assist the reader in making an informed decision about the transferability of the findings to educational institutions outside this particular faith-based educational community.

Limitations of the study were also minimised by investigating possible school, subject and gender interaction effects that could have influenced the CWS and CATBS scores. No significant effects were found that would undermine the findings



of this study, which suggests that results were consistent across school, gender and subject groups. This enhances the validity of claims made about the relationship between students' worldview and their attitudes towards biotechnology.

The concurrent collection of the questionnaire data and the interview data presented additional limitations for this study, as it did not allow issues and ethical arguments identified in the students' responses to the BARBQ to be explicitly addressed and explored in the interview process. While the time-saving mechanism of concurrent data collection still allowed a deeper understanding of students' reasoning about biotechnology than was available through the questionnaire alone, the method did not have the advantage of allowing the interview protocols to be based upon the questionnaire data so that specific connections between students' Christian worldviews and their attitudes towards biotechnology could be explored.

## 8.5 APPLICATION OF THE STUDY FOR EDUCATORS

One of the roles of educators is to help students to think through and understand complex issues so that they can make informed judgements about them. For this to take place within the science classroom, it is essential that science educators understand the underlying belief systems and worldviews that drive much of their attitudes towards biotechnology and implement strategies that develop students' reasoning and ethical thinking.

### 8.5.1 Teaching Socioscientific Issues from a Worldview Perspective

Teaching with an awareness of the worldview of students in the classroom presents some challenges to science educators as it demands that teachers respect students as thinking individuals, while also exposing students to a variety of alternative modes of explaining, so that students can test their personal views against other views (Proper, Wideen, & Ivany, 1988). To achieve this, Proper et al. (1988) suggest that:

Courses ought to be constructed so that a variety of perspectives is openly brought to bear on the subject content. Wherever possible, alternatives to the major paradigms ought to be presented and the limits of each mode of explaining defined. In addition, ...the curriculum needs to begin with the worldviews the students already possess. (p. 557)

The findings of this study provide educators and curriculum developers with a deeper insight into one cultural group of students that can be found in science classrooms, namely, those holding to Christian worldviews, and does so by comparing them to

students who score low on measures of Christian religious belief. This study has demonstrated that a Christian religious belief system does contribute to a more negative view of biotechnology, and it is therefore important that teachers appreciate that the religious beliefs of their students can be a factor in the attitudes that they hold towards biotechnology. Such information can be used by classroom teachers to better equip themselves for their goal of guiding classroom discussions about socioscientific issues, and sensitively challenge students to examine the links between the presuppositions of their worldview and the attitudes they hold regarding controversial issues in science. It also provides additional insight with which to challenge non-religious students in order to gain a better understanding of the worldview and reasoning processes of their peers.

The need for a better understanding of the reasoning and attitudes towards biotechnology of students with a Christian religious belief system is not limited to teachers within faith-based schools (Dávila, 2014; Ladson-Billings, 1995). Dávila (2014) provides this explanation:

Public schools and teachers must be prepared for the reality that some students might be affiliated with minority and/or fundamentalist religious groups while others might not have any affiliations. They must be ready to welcome and serve children of all religious and nonreligious worldviews. Thus, literacy about world religions is as critical to science educators as it is to humanities educators, because members of both groups are expected to guide critical discussions as culturally competent educators. (p. 6)

Further justification for the necessity of science educators to understand the reasoning behind the attitudes of students from a Christian religious background is provided by Reiss (2008), who has commented that:

Traditionally, the ethical frameworks most widely accepted in most cultures arose within systems of religious belief. Nowadays, though, not everyone accepts scripture(s) as a source of authority... Even the various religions differ with respect to ethical matters and many people no longer accept any religious teaching.

Nevertheless, there is still great value in taking seriously the various traditions — religious and otherwise — that have given rise to ethical conclusions. People do not live their lives in isolation: they grow up within particular moral traditions. Even if we end up departing somewhat from the values we received from our families and those around us as we grew up, none of us derives our moral beliefs from first principles, *ex nihilo*, as it were. (p. 894)

### **8.5.2 Teaching for the Development of Informal Reasoning**

As well as equipping science teachers with an understanding of the attitudes and reasoning processes of students holding to Christian worldviews, this study also highlighted the need, within this school context, for classroom initiatives that encourage the increased use of rational and emotive reasoning, and that acknowledge the presuppositions of students' belief systems, including how these presuppositions influence their own attitude towards controversial issues in science.

Because rational reasoning remains an integral part of scientific literacy (Bybee, Carlson-Powell, & Trowbridge, 2008; Cavagnetto, 2010; Dawson & Venville, 2009), researchers have examined students' critical thinking and its role in improving the scientific literacy of students (Bailin, 2002; Hand, Lawrence, & Yore, 1999). While the development of critical thinking skills amongst students cannot be assumed to result in an increase in the frequency of rational informal reasoning amongst students, it seems highly likely that students with a more developed repertoire of critical thinking skills would include more rational reasoning when making judgements about socioscientific issues.

Strategies which have had a positive effect on students' ability to construct more powerful arguments involved students participating in a role-playing game (Lin, Chiu, Hsu, & Wang, 2014), the teaching of philosophy to students (Annis & Annis, 1979), and a call for both teachers and students to better understand and recognise common logical fallacies (Zeidler et al., 1992). The most effective strategy for improving rational reasoning amongst students is likely to be the explicit teaching of critical thinking skills. In a meta-analysis of 117 studies, Abrami et al. (2008) showed that the most effective way to foster critical thinking is to explicitly teach those skills to students. These include skills such as: identifying relevant information, creating categories and classifying items appropriately, testing hypotheses, recognising logical fallacies, and distinguishing between evidence and the interpretation of evidence. Coaching students in these skills as part of a biology program was shown to improve critical thinking amongst seventh-grade students (Zohar, Weinberger, & Tamir, 1994).

While no research could be found into strategies for developing students' emotive informal reasoning, as defined in this study, a number of studies have identified ways

to develop empathy in individuals, which is likely to be reflected in the students' pattern of informal reasoning. Emotive reasoning was categorised as reasoning that included an emotional response to others, such as care, *empathy* and sympathy. Research has shown that students are more likely to develop empathy when their own emotional needs are being met (Barnett, 1987; Kestenbaum, Farber, & Sroufe, 1989). While the role of classroom teachers in providing for a student's emotional needs might be limited, there is much that the school administration and wider school community can do to support students' emotional requirements. Research suggests that teachers should model empathetic behaviour (Pizarro & Salovey, 2002) and provide their students with opportunities to understand, explore, and discuss the perspective of other individuals (Kidd & Castano, 2013; LeBlanc et al., 2003; Ornaghi, Brockmeier, & Grazzani, 2014; Pizarro & Salovey, 2002). Role-playing is one method that may provide an opportunity for students to explore the perspective of others (Varkey, Chutka, & Lesnick, 2006).

When investigating socioscientific issues, science educators need to encourage their students to identify the modes of reasoning that they are utilising and, if necessary, encourage them to actively engage in other modes if they are not already doing so. Given the decreased use of rational reasoning amongst students who accept a Christian worldview, additional coaching might be required to develop the rational reasoning of these students. Because of the reduced incidence of emotive informal reasoning amongst these same students, it could be beneficial for educators to emphasise to these students the importance of empathy in their purported beliefs. While valuable for all students, the importance of implementing strategies to increase students' rational and emotive reasoning might be of additional significance in faith-based schools.

One of the intuitive statements frequently used by students was 'playing God'. Because this research has shown that this term often has a theological meaning for individuals, students need to be encouraged to explain what they mean by this phrase, and start to develop the use of language that is less ambiguous. Van der Zande et al. (2009) has called for teachers to develop activities that invite students to look for the values behind the emotion that often typifies intuitive reasoning. Towards this endeavour, the ethical arguments identified in this study could provide the catalyst for the development of appropriate language to express their concerns. Utilising a

deeper understanding of the source of students' concerns about biotechnology, teachers can encourage students to develop a rational argument for their views that can be developed from their Christian beliefs instead of relying only on intuitive reasoning

### **8.5.3 Teaching for Coherence of Biotechnology Attitudes and Worldview**

Despite a statistically significant relationship between religious belief and concerns about biotechnology, it was evident that students rarely expressed their faith-based principles when attempting to decide the merits of controversial technology. The appreciation of the links between one's own worldview and attitudes or behaviours is not always easily achieved and science educators need to provide scaffolded learning activities to better equip students in the undertaking of this task. The use of ethical frameworks is one such approach that could prove useful for this endeavour, with research by Saunders (2009) and Yap (2012) demonstrating the usefulness of ethical frameworks for teaching socioscientific issues. These two researchers used ethical frameworks, such as rights and duties, utilitarianism, autonomy, and virtue ethics, to guide students in their ability to critically reflect and analyse socioscientific issues and to make rational decisions that reflect their own ethical values. When combined with teacher role-modelling of scientific reasoning, and through the creation of a collaborative and caring learning environment, the use of ethical frameworks can be a valuable strategy for teaching controversial issues in science (Reiss, 2008; Yap, 2012). Further to this, Saunders (2009) developed a model for ethical inquiry that incorporated ethical frameworks and which was successfully used to support science educators by providing them with a structural basis from which a unit of work involving ethical inquiry could be developed. The ethical arguments identified in this study, which describe students' thinking about biotechnology issues, could provide a useful addition to the development of a scaffolded approach to student dialogue that engages students with their personal worldview and explores the link between their worldview and their attitudes to biotechnology.

Because, as this study has shown, many students develop, or are developing, opinions about biotechnology based upon religious beliefs before the completion of their high school education, it is necessary for educators to implement teaching strategies early in a student's education. This way, the necessary reasoning skills will have already been developed as students begin to form their personal views about

controversial issues in science. This is not to suggest that the current views of students' are wrong, or to belittle their opinions; instead, it is necessary to ensure that, when students are evaluating socioscientific issues, it is the result of informed opinion that is scientifically justifiable, while still grounded in their cultural worldview.

While science educators need to be aware of the diversity of views within their classrooms, and encourage students to develop rational arguments for those views, it is equally important that religious educators encourage students to think critically about socioscientific issues from the perspective of their faith tradition. The majority of students in this study who accepted a Christian worldview were unable to demonstrate clear and rational reasoning about why biotechnology was in conflict with their religious worldview. Rational explanations will be increasingly necessary if Christians want a voice in the moral debates that the continual advances in biotechnologies will bring. Through the investigation of socioscientific issues in a manner that acknowledges the religious or non-religious worldview of individuals, and that allows students to discuss and explore the foundations of those differences, it might be possible that educators can avoid the heated and typically futile debates that are so often observed in the public and political arenas when these controversial issues are discussed. Such constructive dialogue could well be what is required to allow those students, whose religious worldview is in tension with that of the rest of Australian society, to find a means of voicing their concerns, with the knowledge that their views are accepted, if not universally shared, in Australia's pluralistic society.

## 8.6 RECOMMENDATIONS FOR FURTHER RESEARCH

This study has, in a limited manner, added to the understanding of the cultural perspective of students with a religious worldview and their thinking about biotechnological issues. From a reflection on the findings of this study, four lines of inquiry present themselves for future research. These are: the further investigation of the qualities of Christian worldviews that correspond to the more negative attitudes towards biotechnology observed in this group of students, the exploration of teaching methodologies to increase the use of rational and emotive informal reasoning, the exploration of teaching methodologies to increase students' rational reasoning from

the foundations of their faith, and the extent that students are reflecting the moral codes of their society when reasoning about socioscientific issues.

While a well-grounded measure of religious worldview was utilised in this study, there remain questions regarding which aspects of the Christian worldviews are responsible for the differences observed in the attitudes and reasoning of students using Christian worldview perspectives and those who do not. For this reason, further research that incorporates different perspectives of religious belief might be necessary to more completely understand the nuances that exist in the relationship between religious belief and attitudes towards biotechnology. One such line of inquiry, which has been tentatively suggested based on the findings of this study, is an investigation into students' views about the nature of God, such as authoritarian views of God and God's involvement in human affairs.

This study identified a decreased reliance on rational and emotive reasoning and an increased use of intuitive reasoning by students with a high level of Christian belief, and it is the first study to find this relationship. Future research should look to confirm this finding and investigate the effectiveness of teaching strategies that might increase the use of rational reasoning by students accepting a Christian worldview and, indeed, amongst science students in general.

Likewise, it would be valuable to assess the implementation of learning activities, including but not limited to the use of ethical frameworks, on their ability to increase the connections between the fundamentals of their worldview and their arguments regarding the application of biotechnologies.

Finally, it would be valuable to identify the extent to which the opinions of the students are their own personally-developed views and how much of their attitudes are merely a reflection of the attitudes of the authoritarian figures in their lives, such as their parents, church leaders, and teachers.

## 8.7 CONCLUSION

The final chapter of this thesis provided a summary of the thesis and outlined the findings relevant to each of the research questions. Chapter 8 then gave a description of the distinctive contributions made by this study to the literature and identified the

limitations of the study, along with some practical applications and suggestions for future research.

This thesis has provided new information about students' reasoning and attitudes about biotechnology from the cultural perspective of a Christian worldview. It has demonstrated that, within the context of a Christian faith-based education system, a student's level of religious belief can be used as a predictor of their attitudes towards biotechnology. This study has also provided preliminary evidence suggesting that the acceptance of a Christian belief system results in altered patterns of informal reasoning. Finally, this research has identified some of the concerns raised by students about biotechnological issues that originate from their faith tradition, and also highlighted the lack of evidence originating from their faith-based traditions to justify their position on the acceptability of biotechnological issue.

After outlining and discussing these findings over the preceding five chapters, it is important to emphasise what has not been found in this study. The research presented here represents a group of students, and while these findings might tell us something about that population, it tells us very little about individuals within that group. It has been demonstrated in this study that religious belief is a predictor of more negative attitudes towards biotechnology, but that does not suggest that the student with a strong religious faith sitting in the classroom is going to be the one who rejects the use of stem cells for medical research and defends his/her position with purely intuitive reasoning. When in the classroom, teachers teach individuals, not populations, and it is for this reason that no teacher of any worth would presuppose a student's opinion about any socioscientific issues based on the box ticked 'religion' on the student's enrolment form. Rather, good teachers should discover for themselves what the student believes about an issue and act as guides who encourage a process of rational reasoning from the core beliefs of their worldview and, while incorporating an understanding of science, come to a consistent and grounded decision about socioscientific issues. It is in this endeavour that this research could play a small part. Through a better understanding of the cultural attitudes and reasoning of students about biotechnology from Christian worldview perspectives, the classroom science teacher might be better equipped to guide and challenge the individuals in his or her classroom, so they will develop into ethically-aware citizens



who can provide an insightful contribution to the present and future debates over socioscientific issues.

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## Appendices

### Appendix A: BARBQ

Administration use only

Consent form received

Yes

No

#### **Biotechnology Attitudes and Religious Belief Questionnaire**

##### **Thankyou for volunteering to participate in this questionnaire**

The following questionnaire contains five parts. Part A consists of questions about your age, school year level, gender and the subjects you are studying so that I have some background information about you. Part B contains true or false questions about your understanding of biotechnology. Part C contains questions about your views on biotechnology issues. Part D contains questions regarding your religious faith. Part E asks you to explain your position on four biotechnology issues.

##### **Please note the following important information regarding the questionnaire.**

- 1. It is not a test*
- 2. It will not contribute towards any part of your school assessment.*
- 3. If a question makes you feel uncomfortable you do not have to answer it.*
- 4. Your answers will be confidential. Because I respect your privacy your names will not be recorded with your answers.*

*If you would like to talk to someone about any of the issues raised in the questionnaire I would encourage you to discuss them with someone you feel comfortable with. This may include your parents, your biology teacher or the school chaplain. The school chaplain is aware of the content of the questionnaire and is available to discuss any concerns that you may have.*

## Biotechnology Attitudes and Religious Belief Questionnaire

### **Part A:** Background Information

Age: 16    17    18                      Year: 11    12                      Gender: M    F

Please circle all of the subjects that you are currently studying

<i>Biology</i>	<i>Physics</i>	<i>Religion &amp; Society</i>	<i>Texts and Tradition</i>
<i>Chemistry</i>	<i>Psychology</i>		

### **Part B:** Knowledge about biotechnology

*Please indicate whether you think that the following statements are True or False.*

1.	DNA stands for Dehydrated Nucleic Acid	T	F
2.	A human has 23 pairs of chromosomes in a regular cell nucleus.	T	F
3.	The chromosomes in the cells of your eyes contain the information for your eye colour.	T	F
4.	The chromosomes in the cells of your kidneys contain the information for your eye colour.	T	F
5.	AIDS is a genetic disease.	T	F
6.	Genetic diseases can be prevented with good hygiene.	T	F
7.	Children resemble their parents because they have the same type of red blood cells.	T	F
8.	A couple have heard from the doctor that they have a one in four chance of having a child with a hereditary disease. This means that if the first child has the disease, the following three children will not.	T	F
9.	Monkeys have three times less genes than humans.	T	F
10.	Genetic modification is the deliberate changing of the hereditary characteristics of living things.	T	F
11.	It is possible to clone a human.	T	F
12.	It is currently prohibited in Australia to clone human embryos.	T	F
13.	The government must always give consent before a genetically modified plant may be grown.	T	F
14.	It is possible to use genetic testing to find out if someone has a higher than average chance of developing some types of cancers.	T	F
15.	It is possible to determine what a baby's IQ or intelligence will be during pregnancy.	T	F
16.	It is possible to change the hereditary qualities of a baby before it is born, so the child will be stronger and smarter.	T	F

17.	It is possible during pregnancy to determine whether a child has Down's Syndrome?	T	F
18.	It is possible to change the hereditary characteristics of an animal so that the animal will make human growth hormone.	T	F
19.	It is possible for the hereditary characteristics of plants to change so that the plants themselves make pesticides against certain insects.	T	F
20.	It is possible to transfer genes from humans to bacteria.	T	F
21.	Ordinary tomatoes have, as opposed to genetically modified tomatoes, no genes.	T	F
22.	If you eat genetically modified fruit your genes may also be genetically modified.	T	F
23.	Bacteria are used in the preparation of yoghurt.	T	F
24.	Biotechnology is used in the production of drugs and hormones.	T	F
25.	Genetically modified animals are always smaller than normal animals.	T	F

### **Part C:** Views about Biotechnology

*Indicate how strongly you agree or disagree with each of the following statements*

		<i>Strongly agree</i>	<i>Agree</i>	<i>Not sure</i>	<i>Disagree</i>	<i>Strongly disagree</i>
1.	Genetically modified foods can help solve food problems in third world countries.	1	2	3	4	5
2.	Biotechnology makes our lives healthier, easier and more comfortable.	1	2	3	4	5
3.	The natural resources of the earth will soon be exhausted because of the advances in biotechnology.	1	2	3	4	5
4.	Genetically modified food is a threat to future generations.	1	2	3	4	5
5.	Further research will solve any dangers associated with genetic modification.	1	2	3	4	5
6.	Genetic research in humans is wrong.	1	2	3	4	5
7.	Genetic modification of food is unnatural.	1	2	3	4	5
8.	Genetic modification of animals is wrong.	1	2	3	4	5
9.	Animals have rights that humans should not interfere with.	1	2	3	4	5
10.	Genetic modification is a threat to nature.	1	2	3	4	5

		<i>Strongly agree</i>	<i>Agree</i>	<i>Not sure</i>	<i>Disagree</i>	<i>Strongly disagree</i>
11.	Genetic modification in humans is 'playing God'.	1	2	3	4	5
12.	Genetic techniques can easily be abused.	1	2	3	4	5
13.	Cloning is safe.	1	2	3	4	5
14.	The genetic modification of bacteria will result in future problems.	1	2	3	4	5
15.	Biotechnology is advancing too fast.	1	2	3	4	5
16.	Genetic modification is good.	1	2	3	4	5
17.	It is difficult to find anything positive about the applications of biotechnology.	1	2	3	4	5
18.	I am not interested in biotechnology.	1	2	3	4	5
19.	Biotechnology is essential for future survival.	1	2	3	4	5
20.	The genetic modification of plants does not exceed the limits that humans should not cross.	1	2	3	4	5
21.	Eating genetically modified food is dangerous.	1	2	3	4	5
22.	Genetic research in animals will benefit human health.	1	2	3	4	5
23.	Genetic research in animals is absolutely necessary.	1	2	3	4	5
24.	Genetic modification is a necessary part of modern life.	1	2	3	4	5
25.	Studying genetics in humans is of no value.	1	2	3	4	5
26.	Genetic research in humans is essential.	1	2	3	4	5
27.	I have faith in science.	1	2	3	4	5
28.	I would buy genetically modified food if it were available at my local supermarket.	1	2	3	4	5
29.	I would not eat at a restaurant if the food they served contained genetically modified ingredients.	1	2	3	4	5
30.	I would buy genetically modified food if it were cheaper than ordinary food.	1	2	3	4	5
31.	I would eat genetically modified food if it tasted better than ordinary food.	1	2	3	4	5
32.	I would eat genetically modified food if it contained less fat than ordinary food.	1	2	3	4	5

*How concerned are you about the following areas of biotechnology?*

		<i>Very concerned</i>	<i>Moderately concerned</i>	<i>Slightly concerned</i>	<i>Unconcerned</i>	<i>Unsure</i>
33.	In Vitro fertilization (IVF)	1	2	3	4	5
34.	Genetic modification of bacteria .	1	2	3	4	5
35.	Genetic modification of plants.	1	2	3	4	5
36.	Genetic modification of animals.	1	2	3	4	5
37.	Genetic modification of humans.	1	2	3	4	5
38.	Cloning of a complete human individual.	1	2	3	4	5
39.	Cloning of human stem cells for the treatment of sick people.	1	2	3	4	5
40.	Cloning of animals.	1	2	3	4	5

*Would you be willing to:*

		<i>Definitely</i>	<i>Probably</i>	<i>Maybe</i>	<i>Probably not</i>	<i>Definitely not</i>
41.	Take a genetic test during you or your partner's pregnancy?	1	2	3	4	5
42.	Take a genetic test to find out whether you are at risk of developing a serious illness when you are older?	1	2	3	4	5
43.	Undergo gene therapy to correct your genes if tests showed that you were highly likely to get a serious genetic disease later?	1	2	3	4	5
44.	Allow your child to undergo gene therapy to improve or change their genes if your child is suffering from a severe or fatal genetic disease?	1	2	3	4	5



**Part D: Views and attitudes towards the Bible and religious faith**

*Circle your response*

1.	How often do you attend religious services? (Not including compulsory school chapel programs but including any other church or religious programs that you attend during the week and on the weekend.)	Never	Once or twice a year	Once a month	Once a week	More than once a week
2.	When you have problems or difficulties in your school, family, or personal life, how often do you seek spiritual comfort?	Always	Often	Sometimes	Rarely	Never

*Indicate how strongly you agree or disagree with each of the following statements*

		Strongly agree	Slightly agree	Neutral	Slightly disagree	Strongly disagree
3.	In general, religious beliefs are very important in my day-to-day life?	1	2	3	4	5
4.	I would consider myself a religious person?	1	2	3	4	5
5.	Jesus Christ was the Divine Son of God.	1	2	3	4	5
6.	The Bible is an important book of moral teachings, but it was not inspired by God anymore than other historical books.	1	2	3	4	5
7.	The concept of God is an old superstition that is no longer needed to explain things in this modern time.	1	2	3	4	5
8.	Through the life, death and resurrection of Jesus, God provided a way for forgiveness of man's sins.	1	2	3	4	5
9.	There is no such thing as a God who is aware of man's actions.	1	2	3	4	5
10.	Jesus was crucified, died, and was buried, but on the third day He rose from the dead.	1	2	3	4	5
11.	Life originated differently than is suggested by the Bible.	1	2	3	4	5
12.	The precise words spoken by God may be found in the Bible.	1	2	3	4	5
13.	The Bible contains God's rules for living.	1	2	3	4	5
14.	The Bible is the product of man's imagination.	1	2	3	4	5
15.	The Bible should be read as God's inspired writings.	1	2	3	4	5
16.	The Bible contains religious truth.	1	2	3	4	5

		Strongly agree	Slightly agree	Neutral	Slightly disagree	Strongly disagree
17.	The Biblical account of creation is accurate.	1	2	3	4	5
18.	Quotations appearing in the Bible are true.	1	2	3	4	5
19.	We can put our trust in the teachings of the Bible.	1	2	3	4	5
20.	Most of the writing in the Bible should be taken literally.	1	2	3	4	5
21.	The miracles reported in the Bible actually occurred.	1	2	3	4	5
22.	The Bible is the ultimate source of truth.	1	2	3	4	5
23.	The Bible accurately predicts future events.	1	2	3	4	5
24.	The Bible is a collection of myths.	1	2	3	4	5
25.	There are more accurate accounts of history than the Bible.	1	2	3	4	5

## Part E

*For each of the following biotechnologies indicate whether you agree or disagree with the technology and provide as much detail as possible why you made your decision, including any ethical or moral principles that influenced your decision.*

[illegible]







### Participation in Further Research

I would like to discuss with you more about your understanding and beliefs regarding biotechnology in an interview at a later date. If you would be happy to participate in an interview please remove this page and complete the details below. Place completed forms in the box provided.

*Indicating a willingness to participate in an interview does not remove your right to withdraw at any stage in the future. Additional information and a separate consent form will be provided if you are selected for an interview.*

Name: \_\_\_\_\_

School: \_\_\_\_\_

Please circle all relevant details

The subjects that you are currently studying include.

*Biology      Chemistry      Physics      Religion & Society*  
*Texts and Traditions*

Gender:            *M*            *F*

Grade:            *Yr 11*            *Yr 12*

## **Appendix B: Interview Protocol**

Adapted from Sadler and Zeidler, 2005

Genetically modified food is food that has been grown from plants that have had their genome changed by deliberately removing genes or adding genes from another organism. This enables scientists to alter specific characteristics of the plants. Plants are often given genes that provide resistance to disease or herbicides. One of the advantages of this is that less chemicals may need to be used.

1. Should genes be inserted into plants like canola so that they are resistant to pests that would damage the crop, why or why not?
2. How would you convince a friend or acquaintance of your position?
3. (If necessary) Is there anything else you might say to prove your point?
4. What underlying principles helped you to make your decision?
5. Scientists have genetically modified crops so that they are drought and disease resistant. These crops could greatly help in the fight against world hunger and malnutrition in third world countries. Does the possibility that this technology could be used to save human lives affect your decision? Why or why not?

Using in vitro fertilization and genetic screening techniques it is possible to screen embryos before they are implanted. Using this technique it is possible to select the gender of a child.

1. Should parents be allowed to use this technique to select the gender of their child. Why or why not?
2. How would you convince a friend or acquaintance of your position?
3. (If necessary) Is there anything else you might say to prove your point?
4. What underlying principles helped you to make your decision?
6. If the parents already had a child that needed medical treatment that could only be provided by a bone marrow transplant from someone with a genetic match, would it be appropriate to screen the embryos so that the second child is a genetic match for their sick sibling (the child is not harmed in this process)? Why or why not?
7. (If necessary) Is there anything else you might say to prove your point?
8. What underlying principles helped you to make your decision?



9. If a gene was found for intelligence would it be appropriate to screen embryos for intelligence? Why or why not?
  10. (If necessary) Is there anything else you might say to prove your point?
  11. What underlying principles helped you to make your decision.
- 4.

In 1996 scientists in Scotland cloned a sheep by taking skin cells from the parent sheep, removing the genetic material and inserting it into an unfertilized egg. The sheep that was born from this process was genetically identical to the parent sheep. Since then many other animals have been cloned including cows and dogs.

1. Do you think that it was right for the scientist to clone a sheep. Why or why not?
2. How would you convince a friend or acquaintance of your position?
3. (If necessary) Is there anything else you might say to prove your point?
4. What underlying principles helped you to make your decision?
5. Would it be acceptable to clone endangered or extinct animals. Why or why not?
6. How would you convince a friend or acquaintance of your position?
7. (If necessary) Is there anything else you might say to prove your point?
8. What underlying principles helped you to make your decision?

A couple and their newborn child (their only child) are involved in a terrible automobile accident. The father dies at the scene of the accident, and the baby is severely injured. The mother sustains only minor cuts and bruises. At the hospital, doctors inform the mother that her baby will undoubtedly die within a matter of days. The woman wants to raise a child that is the product of her now deceased husband and herself. She would like to take cell samples from her dying child so that she can carry and give birth to a genetic clone of the child.

1. Should this woman be able to produce a clone of her dying baby?
2. Why or why not?
3. (If necessary) Is there anything else you might say to prove your point?
4. What underlying principles helped you to make your decision?

## Appendix C: Consent Forms and Information Sheets



### **Curtin University of Technology Science and Mathematics Education Centre**

#### **INFORMATION LETTER FOR PRINCIPALS**

#### **The role of Christian religious beliefs on students' attitudes towards biotechnology in Australian Schools**

Dear

My name is Timothy Pope and I am currently completing a research thesis for my Doctor of Philosophy (Science Education) at Curtin University of Technology.

I am involved in research about the influence of high school student's religious beliefs on their views and understanding of biotechnology issues. To assist me in better understanding how students think about the issues and technology associated with modern biology I would like the VCE students at your school to complete a 30 minute questionnaire. The questionnaire asks students about their understanding of genetics, their beliefs and opinions about modern biology and its technology and also some questions about their religious faith. In addition to the surveys I would like to run a number of group interviews with two or three students at a time. The topics to be discussed are about modern biological technologies and will include; genetically modified food, genetic manipulation in humans, and cloning.

All information provided by the students will be strictly confidential and no individual student or school will be identified. The students will be free to choose not to participate in the questionnaire or to withdraw at any time without affecting their rights or my responsibilities. The students will be reminded that no part of the research will contribute towards assessment for schoolwork. The completed questionnaire will be kept in a locked cabinet for five years, before it is destroyed.

Students will be directed to the school chaplain or another senior staff member to discuss any concerns they may have as a result of completing the questionnaire. It is hoped that parents and caregivers will use this opportunity to discuss with their children the socially significant issues associated with modern biotechnology. The questionnaire will be conducted in a way that minimises any disruption to students' regular classes. A time and date for the interviews and completion of the questionnaire will be set after a discussion with yourself.

Before choosing to participate in this study I would appreciate the opportunity to discuss any concerns that you may have and/or how I can minimize disruption to your school.

This research has been reviewed and given approval by Curtin University of Technology Human Research Ethics Committee (Approval number SMEC-59-09). If you would like further information about the study, please feel free to contact me on Ph 03 9365 9365 or by email: [tim.pope@gilsoncollege.com](mailto:tim.pope@gilsoncollege.com) Alternatively, you can contact my supervisor Dr Vaille Dawson on 08 9266 7484 or [v.dawson@curtin.edu.au](mailto:v.dawson@curtin.edu.au)

Thank you very much for reading this information. If you agree to your school participating in this study could you please sign the consent form on the next page.

Regards

---

Tim Pope  
Secondary Science Teacher  
Gilson College

CONSENT FORM FOR PRINCIPAL

- I have read the information on the attached letter.
  - Any questions I have asked have been answered to my satisfaction.
  - I agree to participate in this research but understand that I can change my mind or stop at any time.
  - I understand that all information provided is treated as confidential
  - I agree that research gathered for this study may be published provided names or any other Information that may identify me/us is not used.
- 

PRINCIPAL CONSENT FORM

Project Title: **The role of Christian religious beliefs on students' attitudes towards biotechnology in Australian Schools**

I have read the information letter above and we agree to participating in this activity realising we may withdraw at any time.

School Name: \_\_\_\_\_

Principal's Name: \_\_\_\_\_

Principal's Signature: \_\_\_\_\_

Date: \_\_\_\_\_

**Curtin University of Technology**  
Science and Mathematics Education Centre

INFORMATION LETTER FOR STUDENT QUESTIONNAIRE

**The role of Christian religious beliefs on students' attitudes towards biotechnology in  
Australian Schools**

Dear Parent/Guardian,

My name is Timothy Pope and I am currently completing a research thesis for my Doctor of Philosophy (Science Education) at Curtin University of Technology.

I am involved in research about the influence of high school student's religious beliefs on their views and understanding of biotechnology issues. To assist me in better understanding how students think about the issues and technology associated with modern biology I would like your son/daughter to complete a 30 minute questionnaire. The questionnaire asks students about their understanding of genetics, their beliefs and opinions about modern biology and its technology and also some questions about their religious faith. Please note that your child does not have to come from a Christian religious tradition to participate, as the research will benefit from a range of religious beliefs.

All information provided by your child will be strictly confidential and no individual student or school will be identified. Your child is free to choose not to participate in the questionnaire or to withdraw at any time without affecting their rights or my responsibilities. No part of this research will contribute towards assessment for schoolwork. The completed questionnaire will be kept in a locked cabinet for five years, before it is destroyed.

The school chaplain or another senior staff member will be available to discuss any concerns your child may have as a result of completing the questionnaire. It is hoped that parents and caregivers will use this opportunity to discuss with their children the socially significant issues associated with modern biotechnology. The questionnaire will be conducted in a way that minimises any disruption to your child's regular classes.

This research has been reviewed and given approval by Curtin University of Technology Human Research Ethics Committee (Approval number SMEC-59-09). If you would like further information about the study, please feel free to contact me on Ph 03 9365 9365 or by email: [tim.pope@gilsoncollege.com](mailto:tim.pope@gilsoncollege.com) Alternatively, you can contact my supervisor Dr Vaille Dawson on 08 9266 7484 or [v.dawson@curtin.edu.au](mailto:v.dawson@curtin.edu.au)

Thank you very much for reading this information. If you agree for your child to participate in this study could you please sign the consent form on the next page and return it to your child's home room teacher.

Regards

---

Tim Pope  
Secondary Science Teacher  
Gilson College

CONSENT FORM FOR STUDENT QUESTIONNAIRE

- I have read the information on the attached letter.
- Any questions I have asked have been answered to my satisfaction.
- I agree to participate in this research but understand that I can change my mind or stop at any time.
- I understand that all information provided is treated as confidential
- I agree that research gathered for this study may be published provided names or any other Information that may identify me is not used.

---

PARENT/GUARDIAN CONSENT FORM

Project Title: **The role of Christian religious beliefs on students' attitudes towards biotechnology in Australian Schools**

I have read the information letter above and I agree to my child participating in this activity realising they may withdraw at any time.

Parent/Guardian Name:

Date:

Parent/Guardian signature:

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STUDENT CONSENT FORM

Project Title: **The role of Christian religious beliefs on students' attitudes towards biotechnology in Australian Schools**

I have read and understood the information letter above that explains the research study and I agree to participate in this research study by completing the questionnaire. I understand that my participation is voluntary and that I may withdraw at any time.

Participant Name:

Date:

Participant Signature:

Dear

Earlier this year you indicated a willingness to participate in a group interview as part of a study looking at student's attitudes to biotechnology. If you are still willing to participate please read the attached information, complete the permission form and return to Mr Pope by Wednesday.

Some light refreshments (drinks and cake) will be served following the interview.

The table below indicates when you have been allocated to attend the interview. Please inform your subject teacher that you will be absent from that class. (Show them this letter). If you are unable to attend the session indicated please see me and I will try and make a swap.

All interviews will be held in the chaplain's lounge

<b><i>Day</i></b>	<b><i>Period</i></b>	
Thursday 11 <sup>th</sup> November	3	
Thursday 11 <sup>th</sup> November	4	
Friday 12 <sup>th</sup> November	2	
Friday 12 <sup>th</sup> November	3	
Friday 12 <sup>th</sup> November	4	

With Thanks

Mr Pope.

**Curtin University of Technology**  
**Science and Mathematics Education Centre**

**INFORMATION LETTER FOR STUDENT INTERVIEWS**  
**The role of Christian religious beliefs on students' attitudes towards biotechnology in**  
**Australian Schools**

Dear Parent/Guardian,

My name is Timothy Pope and I am currently completing a research thesis for my Doctor of Philosophy (Science Education) at Curtin University of Technology.

I am involved in research about the influence of high school student's religious beliefs on their views and understanding of biotechnology issues. To assist me in better understanding how students think about the issues and technology associated with modern biology I would like your son/daughter to participate in a group interview with two or three other students. Please note that your child does not have to come from a Christian religious tradition to participate, as the research will benefit from a range of religious beliefs.

The topics to be discussed are about modern biological technologies will include; genetically modified food, genetic manipulation in humans, and cloning.

All information provided by your child will be strictly confidential and no individual student or school will be identified. Your child is free to choose not to participate in the interview or, if he/she does agree to participate, to not respond to individual questions. Your child may withdraw from the research at any time without affecting their rights or my responsibilities. No part of this research will contribute towards assessment for schoolwork. The interview recordings and transcribed information will be kept in a locked cabinet for five years, before it is destroyed.

The school chaplain or another senior staff member will be present during the interview and will be available after the interview to answer any questions that students may have about the issues discussed during the interview. It is hoped that parents and caregivers will use this opportunity to discuss with their children the socially significant issues associated with modern biotechnology. The interviews will be conducted in a way that minimizes any disruption to your child's regular classes.

This research has been reviewed and given approval by Curtin University of Technology Human Research Ethics Committee (Approval number Smec-59-09). If you would like further information about the study, please feel free to contact me on Ph 03 9365 9365 or by email: [tim.pope@gilsoncollege.com](mailto:tim.pope@gilsoncollege.com) Alternatively, you can contact my supervisor Dr Vaille Dawson on 08 9266 7484 or [v.dawson@curtin.edu.au](mailto:v.dawson@curtin.edu.au)

Thank you very much for reading this information. If you agree for your child to participate in this study could you please sign the consent form at the bottom of this page and return it to your child's homeroom teacher.

Regards

---

Tim Pope  
Secondary Science Teacher  
Gilson College

CONSENT FORM FOR STUDENT INTERVIEWS

- I have read the information on the attached letter.
  - Any questions I have asked have been answered to my satisfaction.
  - I agree to participate in this research but understand that I can change my mind or stop at any time.
  - I understand that all information provided is treated as confidential
  - I agree for this interview to be taped/recorded.
  - I agree that research gathered for this study may be published provided names or any other Information that may identify me/us is not used.
- 

PARENT/GUARDIAN CONSENT FORM

Project Title: **The role of Christian religious beliefs on students' attitudes towards biotechnology in Australian Schools**

I have read the information letter above and I agree to my child participating in this activity realising they may withdraw at any time.

Parent/Guardian Name:

Date:

Parent/Guardian signature:

---

STUDENT CONSENT FORM

Project Title: **The role of Christian religious beliefs on students' attitudes towards biotechnology in Australian Schools**

I have read and understood the information letter above that explains the research study and I agree to participate in this research study by completing the questionnaire. I understand that my participation is voluntary and that I may withdraw at any time.

Participant Name:

Date:

Participant Signature:



## Appendix D: Differences in Attitudes Towards Biotechnology and Religious Belief Scales: Gender, Subjects Studied, School and Year Level.

Gender differences in attitudes towards biotechnology and religious belief scales. Showing item Mean, Standard Deviation *t*-test and effect size.

BARBQ <sub>quant</sub> scale	Item Mean		Item <i>SD</i>		Difference	
	Male	Female	Male	Female	Effect Size ( <i>d</i> )	<i>t</i>
<b>Attitudes about Biotechnology</b>						
<u>Cognitive</u>						
Biotechnology	0.76	0.72	0.16	0.14	0.26	1.49
Beliefs About Biotechnology	3.46	3.17	0.60	0.51	0.52	3.4***
<u>Affective</u>						
Emotions	2.87	2.51	0.63	0.52	0.62	4.02***
Inevitability	3.27	3.02	0.58	0.57	0.43	2.74**
Concerns	3.03	2.70	0.93	0.81	0.37	2.41*
<u>Behavioural</u>						
GM Food Intentions	3.30	2.93	0.87	0.86	0.42	2.69**
Medical Intentions	3.64	3.45	0.86	0.91	0.21	1.42
<b>Christian religious belief</b>						
Christian Orthodoxy	3.81	4.38	1.24	0.86	0.53	3.48***
Biblical Literalism	3.57	4.15	1.18	0.94	0.54	3.53***
Religiosity	3.00	3.46	1.27	1.21	0.37	2.34**

Note. Male (*n* = 72); Female (*n* = 95)

\**p* < 0.05, \*\**p* < 0.01, \*\*\**p* < 0.001

Average Item Mean, Average Item Standard Deviation, Effect Size and *t*-test for differences between studying Biology and not studying Biology in BARBQ scores.

BARBQ <sub>quant</sub> scale	Item Mean		Item <i>SD</i>		Difference	
	no Biology	Biology	no Biology	Biology	Effect Size ( <i>d</i> )	<i>t</i>
<b>Attitudes about Biotechnology</b>						
<u>Cognitive</u>						
Biotechnology	0.72	0.75	0.15	0.15	0.2	1.35
Beliefs About Biotechnology	3.36	3.12	0.61	0.49	0.43	1.85
<u>Affective</u>						
Emotions	2.67	2.61	0.59	0.60	0.1	0.77
Inevitability	3.13	3.11	0.59	0.57	0.03	0.21
Concerns	2.99	2.57	3.48	3.56	0.11	3.18**
<u>Behavioural</u>						
GM Food Intentions	3.12	3.05	0.90	0.80	0.08	0.53
Medical Intentions	3.48	3.56	0.91	0.88	0.08	0.63
<b>Christian religious belief</b>						
Christian Orthodoxy	4.10	4.20	1.06	1.09	0.09	0.64
Biblical Literalism	3.84	4.02	1.08	1.04	0.16	1.08
Religiosity	3.12	3.50	1.24	1.23	0.3	1.90*

Note. No Biology (*n* = 109); Biology (*n* = 68)

\**p* < 0.05, \*\**p* < 0.01, \*\*\**p* < 0.001

Average Item Mean, Average Item Standard Deviation, Effect Size and *t*-test for differences between studying Chemistry and not studying Chemistry in BARBQ scores.

BARBQ <sub>quant</sub> scale	Item Mean		Item <i>SD</i>		Difference	
	no Chemistry	Chemistry	no Chemistry	Chemistry	Effect Size ( <i>d</i> )	<i>t</i>
<b>Attitudes about Biotechnology</b>						
<u>Cognitive</u>						
Biotechnology	0.71	0.79	0.16	0.09	0.61	3.31***
Beliefs About Biotechnology	3.32	3.24	0.59	0.52	0.14	0.77
<u>Affective</u>						
Emotions	2.66	2.64	0.63	0.50	0.03	0.23
Inevitability	3.11	3.14	0.62	0.47	0.05	0.34
Concerns	2.81	2.85	0.87	0.88	0.04	0.27
<u>Behavioural</u>						
GM Food Intentions	3.11	3.04	0.89	0.80	0.08	0.49
Medical Intentions	3.47	3.57	0.93	0.82	0.11	0.67
<b>Christian religious belief</b>						
Christian Orthodoxy	3.97	4.48	1.15	0.77	0.52	3.01***
Biblical Literalism	3.81	4.12	1.1	0.90	0.3	1.80*
Religiosity	3.33	3.1	1.23	1.27	0.18	0.93

Note. No Chemistry (*n* = 121); Chemistry (*n* = 56)

\**p* < 0.05, \*\**p* < 0.01, \*\*\**p* < 0.001

Average Item Mean, Average Item Standard Deviation, Effect Size and *t*-test for differences between studying Physics and not studying Physics in BARBQ scores.

BARBQ <sub>quant</sub> scale	Item Mean		Item <i>SD</i>		Difference	
	no Physics	Physics	no Physics	Physics	Effect Size ( <i>d</i> )	<i>t</i>
<b>Attitudes towards Biotechnology</b>						
<u>Cognitive</u>						
Biotechnology	0.73	0.755	0.14	0.18	0.15	0.83
Beliefs About Biotechnology	3.27	3.40	0.57	0.60	0.22	1.13
<u>Affective</u>						
Emotions	2.63	2.78	0.60	0.55	0.26	1.34
Inevitability	3.09	3.22	0.59	0.53	0.23	1.16
Concerns	2.79	2.99	0.83	1.05	0.21	1.17
<u>Behavioural</u>						
GM Food Intentions	3.06	3.21	0.88	0.76	0.18	0.94
Medical Intentions	3.51	3.49	0.91	0.82	0.02	0.17
<b>Christian religious belief</b>						
Christian Orthodoxy	4.19	3.88	1.04	1.15	0.28	1.50
Biblical Literalism	3.93	3.80	1.08	1.03	0.12	0.66
Religiosity	3.35	2.91	1.23	1.28	0.35	1.80

Note. No physics (*n* = 143); *Physics* (*n* = 34)

\**p* < 0.05, \*\**p* < 0.01, \*\*\**p* < 0.001

Average Item Mean, Average Item Standard Deviation, Effect Size and *t*-test for differences between studying Psychology and not studying Psychology in BARBQ scores.

BARBQ <sub>quant</sub> scale	Item Mean		Item <i>SD</i>		Difference	
	no Psychology	Psychology	no Psychology	Psychology	Effect Size ( <i>d</i> )	<i>t</i>
<b>Attitudes towards Biotechnology</b>						
<u>Cognitive</u>						
Biotechnology	0.74	0.73	0.16	0.14	0.06	0.37
Beliefs About Biotechnology	3.32	3.25	0.55	0.62	0.11	0.78
<u>Affective</u>						
Emotions	2.71	2.56	0.59	0.61	0.24	1.66
Inevitability	2.71	2.56	0.59	0.59	0.25	1.79
Concerns	2.88	2.74	0.87	0.89	0.15	0.97
<u>Behavioural</u>						
GM Food Intentions	3.17	2.97	0.80	0.94	0.22	1.46
Medical Intentions	3.59	3.38	0.84	0.97	0.23	1.51
<b>Christian religious belief</b>						
Christian Orthodoxy	4.13	4.13	1.07	1.07	0	0.01
Biblical Literalism	3.91	3.90	1.07	1.06	0	0.07
Religiosity	3.24	3.31	1.25	1.26	0.05	0.33

Note. No Psychology (*n* = 110); Psychology (*n* = 67)

\**p* < 0.05, \*\**p* < 0.01, \*\*\**p* < 0.001

Average Item Mean, Average Item Standard Deviation, Effect Size and *t*-test for differences between Year 11 and Year 12 students in BARBQ scores.

BARBQ <sub>quant</sub> scale	Item Mean		Item <i>SD</i>		Difference	
	Yr 11	Yr 12	Yr 11	Yr 12	Effect Size ( <i>d</i> )	<i>t</i>
<b>Attitudes towards Biotechnology</b>						
<u>Cognitive</u>						
Biotechnology	0.74	0.72	0.16	0.14	0.13	0.82
Beliefs About Biotechnology	3.24	3.36	0.48	0.66	0.2	1.41
<u>Affective</u>						
Emotions	2.61	2.71	0.54	0.64	0.16	0.98
Inevitability	3.10	3.15	0.53	0.63	0.08	0.45
Concerns	2.87	2.80	0.87	0.89	0.07	0.52
<u>Behavioural</u>						
GM Food Intentions	3.10	3.08	0.80	0.93	0.02	0.12
Medical Intentions	3.36	3.64	0.89	0.89	0.31	2.07
<b>Christian religious belief</b>						
Christian Orthodoxy	4.08	4.16	1.04	1.11	0.07	0.53
Biblical Literalism	3.75	4.05	1.01	1.11	0.28	1.87
Religiosity	3.20	3.34	1.11	1.37	0.11	0.73

Note. Yr 11 (*n* = 88); Yr 12 (*n* = 86)

\**p* < 0.05, \*\**p* < 0.01, \*\*\**p* < 0.001

Average Item Mean, Average Item Standard Deviation, Effect Size and F for differences between schools in BARBQ scores.

BARBQquant scale	Item Mean			Item SD			Difference
	School 1	School 2	School 3	School 1	School 2	School 3	F
<b>Attitudes towards Biotechnology</b>							
<u>Cognitive</u>							
Biotechnology	0.71	0.79	0.75	0.16	0.13	0.15	5.73**
Beliefs About Biotechnology	3.25	3.35	3.40	0.51	0.67	0.57	0.75
<u>Affective</u>							
Emotions	2.57	2.80	2.70	0.52	0.66	0.70	2.80
Inevitability	3.09	3.22	2.99	0.53	0.58	0.82	1.56
Concerns	2.68	3.16	2.54	0.77	0.92	1.06	6.85
<u>Behavioural</u>							
GM Food Intentions	3.08	3.16	2.95	0.82	0.89	1.02	0.38
Medical Intentions	3.49	3.58	3.36	0.88	0.89	1.06	0.39
<b>Christian religious belief</b>							
Christian Orthodoxy	4.04	4.35	3.93	1.01	1.01	1.49	1.89
Biblical Literalism	3.88	4.00	3.75	1.02	1.08	1.28	0.41
Religiosity	3.33	3.17	3.21	1.19	1.34	1.36	0.29

Note. School 1 ( $n = 104$ ); School 2 ( $n = 57$ ); School 3 ( $n = 16$ )

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$